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GEOLOGY OF NEW BRUNSWICK

FIELD GUIDE TO EXCURSIONS

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TRIP A-1. by L. T. Trembath, University of New Brunswick.

ZEOLITE MINERAL ASSEMBLAGE, GRAND MANAN ISLAND, NEW BRUNSWICK

The Triassic basalts of Grand Manan Island have been divided into two units:

(1) A series of small flows and sills termed the multiple flow unit which is best exposed along the section of coast-line called the Seven Days Work, and

(2) A 500' thick sill which extends over most of the island and is best exposed as 200 - 300' cliffs on the western side of the island. The basaltic rocks are in fault contact with the Precambrian rocks and the base of the basaltic units are in conformable contact with the underlying red-bed sediments of the Annapolis formation. The 500' thick sill appears to be in both conformable and transgressive contact with the multiple flow-sill unit.

ZEOLITES

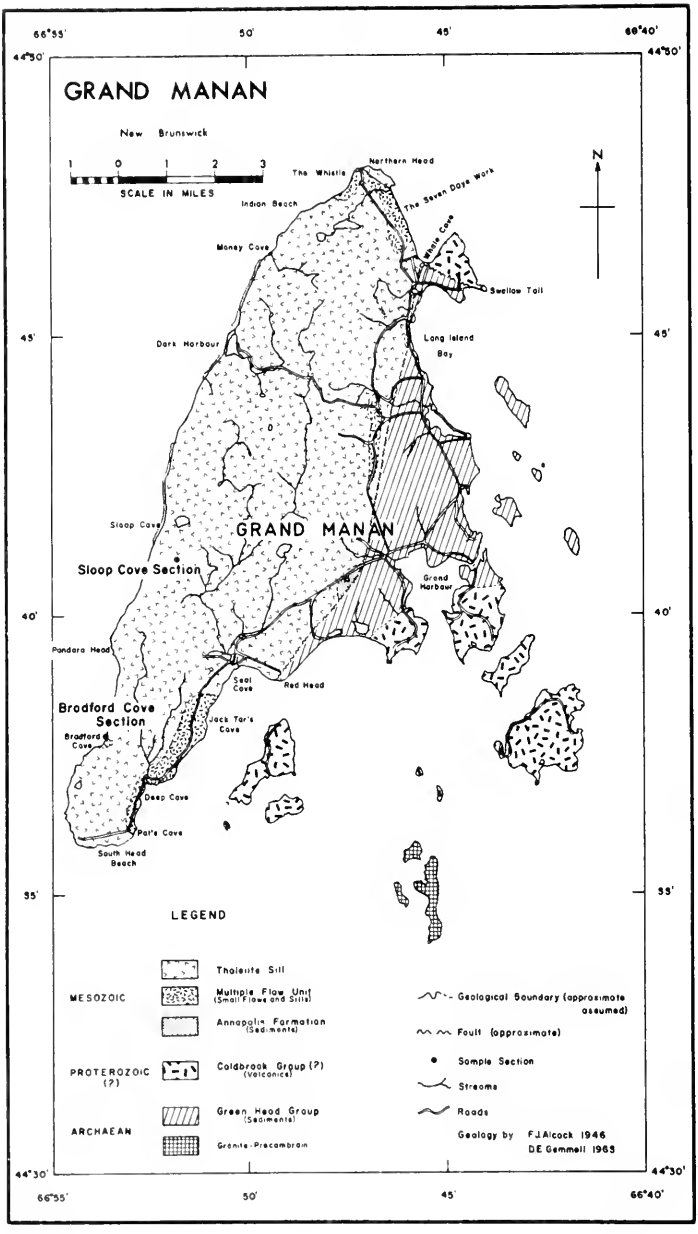
The zeolites occur as crystal aggregates, radiating masses, narrow veins or as infillings in amygdaloidal basalts. The most accessible locations are along the section of coastline known as the Seven Days Work and occur within most of the units within the multiple flow-sill sequence. The most abundant zeolites are heulandite, epistilbite, stilbite, and scolecite. Natrolite, chabazite, apophyllite and laumontite are not as abundant. Microcline, albite, calcite and quartz are found in association with the zeolites and native copper may be found near contacts.

AMYGDALOIDAL BASALTS

Usually the irregularly shaped amygdules are filled with heulandite, stilbite and epistilbite. Commonly the zeolites are coated with a green mineral which may be montmorillonite, chlorite or serpentine. Pipe amygdules occur near the bottom of some flows or sills. Normally these are small vertical amygdules from 2 - 15 mm. in diameter and up to about 15 cm. in length.

AMYGDALOIDAL PIPES

Larger pipe structures of coarsely amygdaloidal (0.5 - 1 cm.) basalts from 1 - 10 cm. in diameter and up to several meters in


GRAND MANAN
New Brunswick
1 0 1 2 3
SCALE IN MILES
N
66°55'
50'
45'
66°40'
44°50'
45'
40'
35'
44°30'
The Whistle
Northern Head
The Seven Days Work
Indian Beach
Money Cove
White Cove
Swallow Tail
Dark Harbour
Long Island Bay
Sloop Cove
GRAND MANAN
Sloop Cove Section
Grand Harbour
Pandora Head
Seal Cove
Red Head
Brodford Cove Section
Jack Tar's Cove
Brodford Cove
Deep Cove
Pat's Cove
South Head Beach
LEGEND
Tholeiite Sill
MESOZOIC
Multiple Flow Unit (Small Flows and Sills)
Annapolis Formation (Sediments)
PROTEROZOIC (?)
Coldbrook Group (?) (Volcanics)
ARCHAEAN
Green Head Group (Sediments)
Granite-Precambrian
Geological Boundary (approximate assumed)
Fault (approximate)
Sample Section
Streams
Roads
Geology by F.J.Alcock 1946
D.E.Gemmell 1983

length are found in a near vertical attitude within either massive basalt or more finely amygdaloidal basalt. In a few instances two or more pipes coalesce upwards to form one large pipe or more rarely one large pipe separates into two or more smaller pipes.

COLUMNAR JOINTING

Columnar jointing is common in the 500' unit and in some of the more massive multiple flow units. The joints are normally in a near vertical attitude and may have oxidation rings concentric to the columnar joint pattern and extending the length of the column.

LOG AND DIRECTIONS

Assemble at the Grand Manan Ferry Service Wharf in Black's Harbour for the 10.15 ferry, Friday, October 12th and proceed by car ferry to North Head, Grand Manan Island. Please arrive in Black's Harbour one hour prior to departure time as we will reduce the number of cars to a minimum at this point. (Car transport is six dollars). Meals are normally available on the ferry. Arrival time – 12.00 p.m.

MILEAGE

0.0	Turn left (south) on leaving wharf.
0.2	Pass Shorecrest Lodge where we will be staying the night.
0.3	Junction of main highway and Whistle Road.
2.6	Bridge over Eel Brook.
2.7	Park cars in parking area adjacent to town dump. Take the trail to Eel Brook Beach (approximately 1/2 mile).

Traverse along the cliff section known as Seven Days Work. Return to Shorecrest Lodge for dinner. After dinner a brief trip will be made to the north end of the island. Follow the same route along the Whistle Road to the end of the road at North Head. Walk to the shore and continue west about 1500' along the shore.

SATURDAY, OCTOBER 13

Leaving Shorecrest Lodge at 8.30 a.m. Proceed to Whale Cove via the Swamp road which leaves the main highway about 100 yards east of the junction with the Whistle Road. Traverse along the south end of the cliff section towards Northern Head. Return to ferry wharf by 11.15 and return to mainland by 12.15 ferry.

TRIP A-2, by N. Rast and R. H. Grant, The University of New Brunswick.

THE VARISCAN FRONT IN SOUTHERN NEW BRUNSWICK

INTRODUCTION

Zones of post-Carboniferous (post-Pennsylvanian) deformation in New Brunswick have been recognized for many years (Bailey, et al; 1880). Poole, (1967) has referred to the movements causing the deformation as the Maritime Disturbance. Recent work by ourselves (1973) has shown that the disturbance is associated with large-scale over-thrusting involving both the Carboniferous cover and the pre-Carboniferous basement. The excursion is planned to marshal the evidence for the post-Carboniferous movements which we correlate with the Variscan Orogeny of Europe.

STRATIGRAPHY AND SEDIMENTATION

The stratigraphic succession (Fig. 1) varies in relation to the overthrust zone. Generally Mississippian (Mispec) volcanics and the associated grey and red clastic sediments are present only to the southeast of the overthrust zone except in the Kennebecasis region where the Mississippian Kennebecasis conglomerate probably rests with an angular unconformity on the older formations. This suggests that the present-day line of overthrusting follows approximately the line of overstep of the Pennsylvanian over the Mississippian onto the older rocks. In the area affected by overthrusting the Mississippian-Pennsylvanian succession varies from place to place and in most cases the sediments appear to be proximally derived. This is especially so with respect to conglomerates where pebbles can be related to the immediately adjacent basements. The presence of abundant plant remains, especially in the Pennsylvanian, occasional coals (Wright and Clements, 1943) and coarse, often ill-sorted, angular rock debris suggests basically subaerial derivation. However, the presence of marine incursions can be deduced from occasional pillow lavas such as those on west Saint John (West Beach Formation). In Lepreau the rocks correlated with the Balls Lake Formation contain an extensive development of ignimbrites (welded ash-flow deposits) which can also be related stratigraphically to similar rocks of the Mount Pleasant and Harvey areas to the north (van de Poll, 1962).

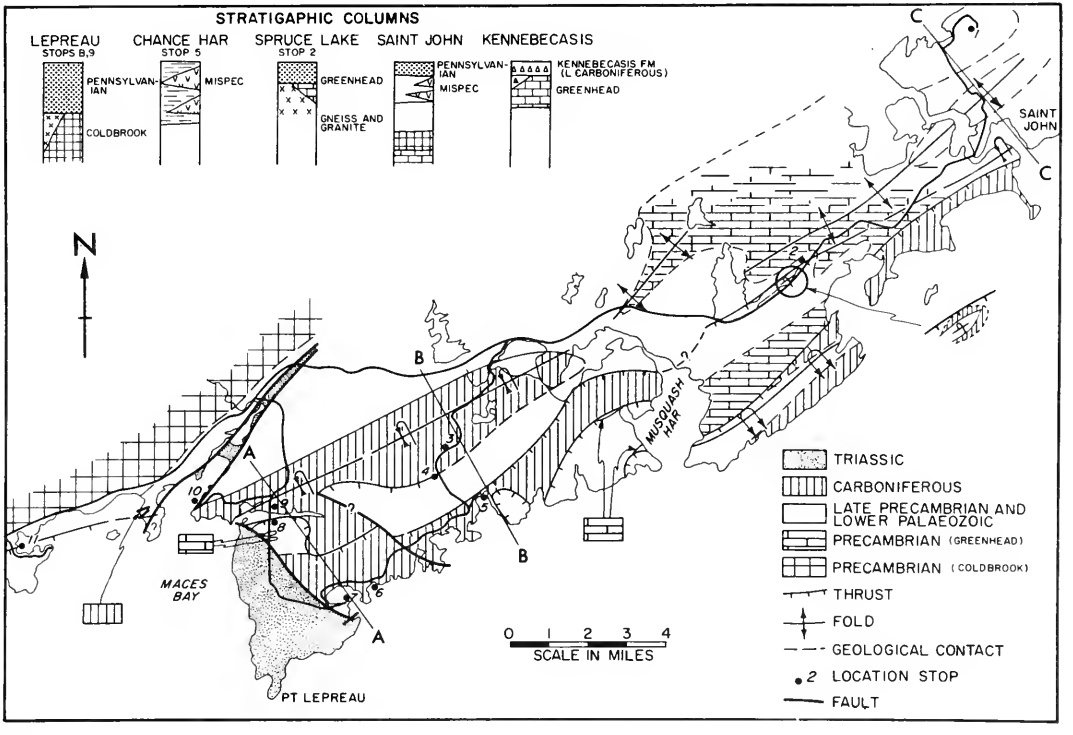

STRATIGAPHIC COLUMNS
LEPREAU
STOPS 8,9
PENNSYLVAN-IAN
COLDBROOK
CHANCE HAR
STOP 5
MISPEC
SPRUCE LAKE
STOP 2
GREENHEAD
GNEISS AND GRANITE
SAINT JOHN
PENNSYLVAN-IAN
MISPEC
KENNEBECASIS
KENNEBECASIS FM (L CARBONIFEROUS)
GREENHEAD
N
SAINT JOHN
MUSQUASH HAR
MACES BAY
PT LEPREAU
SCALE IN MILES
0 1 2 3 4
TRIASSIC
CARBONIFEROUS
LATE PRECAMBRIAN AND LOWER PALAEOZOIC
PRECAMBRIAN (GREENHEAD)
PRECAMBRIAN (COLDBROOK)
THRUST
FOLD
GEOLOGICAL CONTACT
2 LOCATION STOP
FAULT

Fig. 1

Red Pennsylvanian sandstones and conglomerates at Spruce Lake (Stop 3) show the proximate nature of the deposit particularly well, since fragments in the sandstone can be directly matched with adjacent gneisses and granites.

From the stratigraphic columns it is obvious that in the southern part of the ground the Pennsylvanian oversteps the Mississippian (Mispec Group) from the southeast to the northwest.

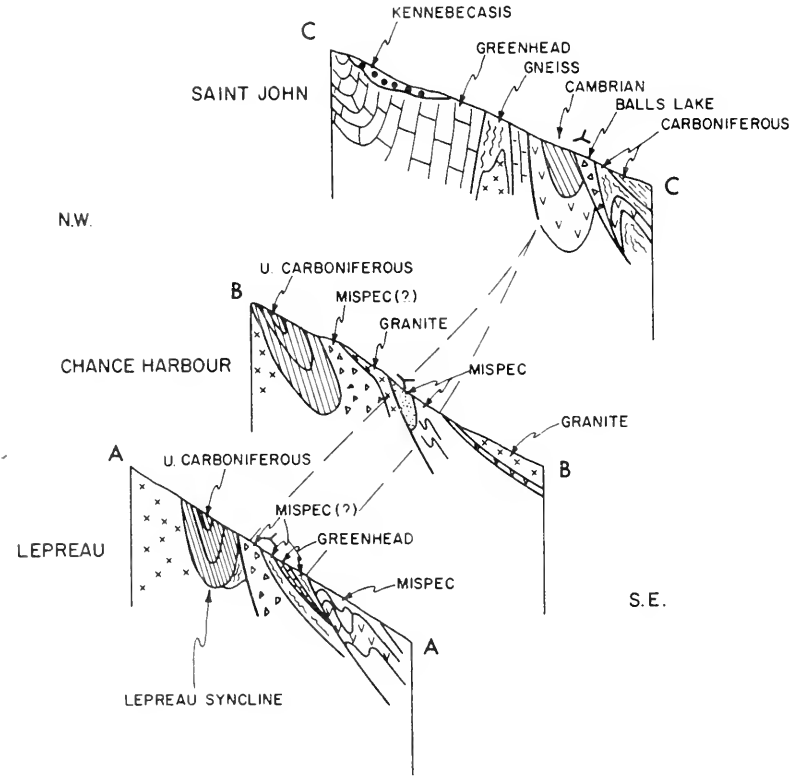


Fig. 2

STRUCTURE

The structure of the ground is regionally represented by three cross-sections (Fig. 2). Only the relationships to the southeast of the Beaver Harbour – Bellisle fault are discussed.

To the southeast of the Beaver Harbour – Bellisle fault the structure is governed by extensive overthrusting (Fig. 2) involving Carboniferous rocks. While those belonging to the Mispec Group are especially strongly deformed, the Lancaster Formation has also been affected, resulting in strong folding, in occasional overturning and in the development of cleavage.

The section at Little Lepreau Basin is especially instructive. Here the Lepreau Syncline with a core of Lancaster Formation rocks has a sub-vertical northern limb and an overturned southern limb. On the southern limb, cleavage dipping at an angle of 45-50° is more gently inclined than the bedding and affects rocks bearing fossil plants. On the southern side of the Little Lepreau basin, overturned sediments and volcanics belonging to the Mispec Group are interpreted as being in a thrust contact against the Lancaster Formation. Still further south, cleaved marbles which have been correlated with the Precambrian Greenhead Formation are interpreted as thrust slices. From the northern side of Little Lepreau Basin southwards the cleavage acquires a progressively lower dip. This cleavage appears to be penecontemporaneous with thrusting and is the first post-Carboniferous tectonic structure (S_{1C}). In Dipper Harbour it is refolded (Fig. 3a) by second generation, post-Carboniferous folds with attendant axial planar cleavage (S_{2C}). The first cleavage has a generalized east-northeast strike and a south-southeast dip. The second cleavage which is well displayed in both Dipper Harbour and Chance Harbour has a similar strike but dips gently to the northwest.

In places a sporadically developed weak third cleavage (S_{3C}) is also present (Fig. 3b) and which is axial planar to microfolds trending north-south to northwest-southeast. At Pocologan (Stop 10) the folds belonging to this episode are particularly well-developed.

REGIONAL CORRELATIONS

The post-Carboniferous movements are clearly later than Westphalian B and are pre-Triassic. Therefore we have suggested that these movements correlate on the one hand with the Appalachian deformation of southern New Brunswick and on the other

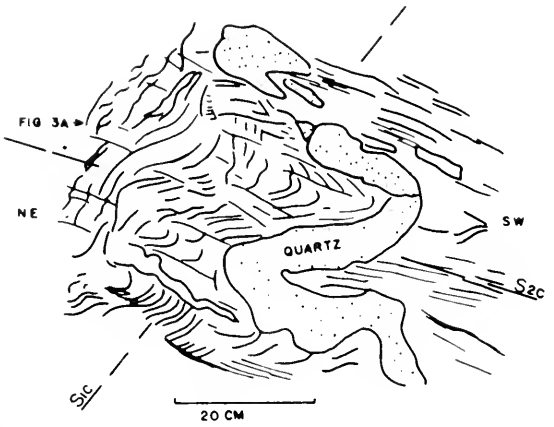
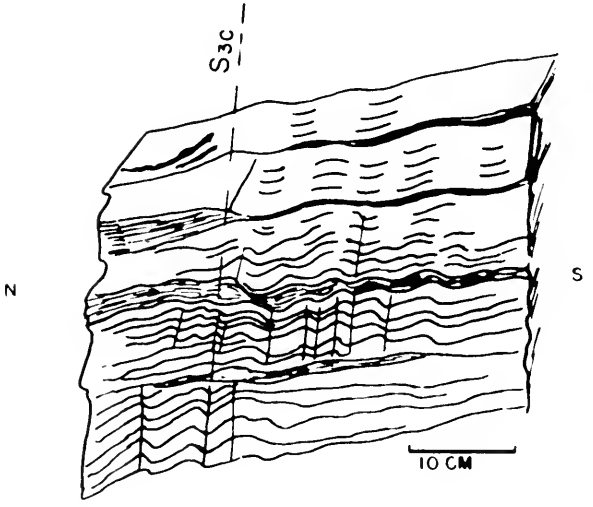


Fig. 3a



HORIZONTAL SCHISTOSITY DEFORMED BY VERTICAL CRENULATION CLEAVAGE S_{3C}

Fig. 3b

hand with the Variscan (Hercynian) movements of the British Isles, suggesting a much closer pre-Mesozoic drift unity at least along the strike of the Caledonian – Appalachian orogenic belt.

LOG AND STOPS

MILEAGE

0 STOP 1 – *University Ground* – Kennebecasis Conglomerate Lower Carboniferous (Visean?) conglomerate and sandstones, bedded with gentle dip containing fragments derived mainly from Precambrian Greenhead limestones and quartzites, granites and gneisses.

10.2 STOP 2 – *Spruce Lake* – Steeply-dipping, overturned U. Carboniferous (Lancaster Formation) red sandstones with pebbles of granite, gneiss and feldspars in a faulted (thrust) contact against gneisses and granites related to the continuation of the Indiantown anticline.

24.0 STOP 3 – *Chance Harbour Road* – Steeply dipping red sandstones shales and micro-conglomerates of the Lepreau syncline. The rocks are moderately deformed.

24.4 STOP 4 – *Chance Harbour Road* – Reddish volcanic mudflows with interbedded sediments. Weakly cleaved. It is possible that these rocks are L. Carboniferous rather than Precambrian as indicated on the G.S.C. sheet. If they are Carboniferous then the cleavage is the expression of the second Carboniferous deformation.

26.4 STOP 5 – *East Chance Harbour* – Coastline exposures of refolded Carboniferous. Tight folds with first Carboniferous axial plane cleavage (S_{1C}) refolded (Fig. 4a) and cut by the (S_{2C}) crenulation cleavage. The rocks consist of Lower Carboniferous sandstones and acid volcanic tuffs (Mispec Group).

30.5 STOP 6 – *Round Meadow Cove* – Cleaved (S_{1C}) ignimbrites of the Mispec Group. Cleavage dips at a shallower angle than the stratification. Therefore the rocks are overturned. Sheets of diabase intrude the ignimbrites and are deformed together with them. Cycloidal joints have developed in the ignimbrites.

32.9 STOP 7 – *Dipper Harbour* – Deformed tuffaceous conglomerate with strongly flattened carbonate clasts is affected by S_{1C} and S_{2C} cleavages which dip at small

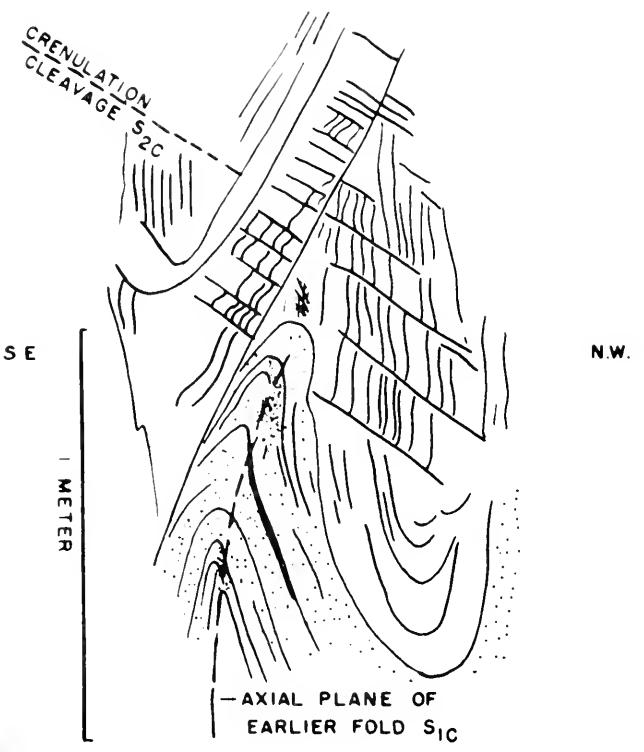


Fig. 4a

angles. Good second Carboniferous minor folds F_{2C} are observed showing a pronounced asymmetric style (Fig. 4b). The rocks here have been formerly mapped as Precambrian Greenhead Formation, but across the harbour they are clearly interbedded with rocks of the Mispec succession.

38.5 STOP 8 — *Little Lepreau South* — Short traverse from Little Lepreau Basin causeway to a quarry on the dirt road running due south toward Point Lepreau. Part of this succession is shown as Precambrian on the Geological Survey map, but it appears to be part and parcel of the Mispec Group. The sequence is overturned and from Little Lepreau Basin to the quarry involves ashes,

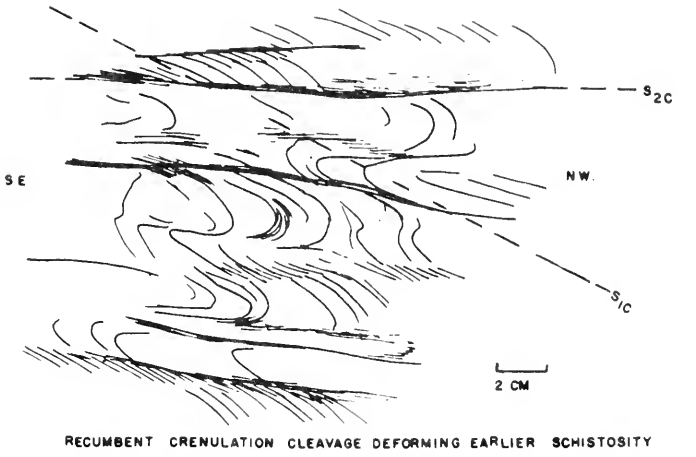


Fig. 4b

mudflows, flowbanded rhyolite and banded metasediments. The latter becoming younger to the north towards the junction with the Lancaster Formation. Structurally overlying the banded sediments are cleaved marbles interpreted as slices of Greenhead Formation.

38.7 STOP 9 – *Little Lepreau North* – Dark grey sandstone and slate of Carboniferous age representing an overturned limb of the Lancaster syncline. Bedding and cleavage strike 81 and dip 50 to 60° south with cleavage dipping slightly less than bedding. Fossil leaves well preserved.

41.6 STOP 10 – *Lepreau Harbour* – Coarsely current-bedded Lancaster Sandstones with plant remains and subvertical bedding younging toward the south representing the steep northern limb of the Lepreau syncline. (If tides are unsuitable this stop will be omitted.)

55.5 STOP 11 – *Pocologan* – Overthrust junction between the Pocologan granite and Precambrian Coldbrook volcanic rocks. The granite is brecciated and cleaved (S_{1C}) and the cleavage is refolded on folds trending between 145° and 180°. These folds are interpreted as F_{3C}.

TRIP A-3 and B-6, by G. E. Pajari, The University of New Brunswick.

THE GRANITIC ROCKS OF SOUTHWESTERN NEW BRUNSWICK

INTRODUCTION

The geologic record in the rocks of southwestern New Brunswick encompasses the time interval between the Precambrian and the Triassic. The rocks have been involved in two documentable deformation events – the traditionally accepted Acadian Orogeny, the effects of which were regional, and the Variscan-Appalachian Orogeny (Rast and Grant, 1973b), which affected the rocks along the Fundy coast in the eastern half of the area of Figure 1.

Post-orogenic intrusions (H and I, Fig. 1) compose the largest area of plutonic rocks. The largest of these intrusions is the St. George Pluton (550 sq. miles) which is composed of a calc-alkali suite consisting of adamellite, granite and gabbro in order of abundance. Rocks intermediate in composition between gabbro and adamellite occur in small volumes in the western part of the pluton and can be demonstrated to be the products of reaction between a gabbro and later felsic intrusions (Stops 2-9). A Rb/Sr whole rock isochron age of 400 my has been obtained for the rocks of the westernmost part of the pluton (R. Cormier, written communication, 1972). A smaller layered tholeiitic ultrabasic intrusion occurs at St. Stephen, just off the northwest end of the St. George Pluton. This intrusion consists of a basal peridotite overlain in sequence by an anorthosite zone and gabbro. This body is intruded by felsic rocks similar to those of the St. George intrusions (K. Butt, oral communication, 1973). Four stocks north of the St. George Pluton (K, Fig. 1) consisting of adamellite have given K/Ar ages between 320 and 338 my (Ruitenberg et al, 1970). All these intrusions have not been deformed nor metamorphosed during the Acadian Orogeny.

Older intrusive rocks which are metamorphosed and/or possess a tectonic fabric occur in the southeastern part of the area constituting all of unit F (Stops 13 and 14) and most of unit C (Stops 15, 17, 19; Fig. 1). An intrusive body consisting of unaltered adamellite within unit C is tentatively correlated with the St. George intrusion (Stop 18). Many of the intrusive rocks in this area were transported in the Variscan-Appalachian (Stop 17 and 19; Rast and Grant, this guidebook) or in earlier thrust sheets (Stop 14; Helmstaedt, 1968; Rast, oral communication). Geologic

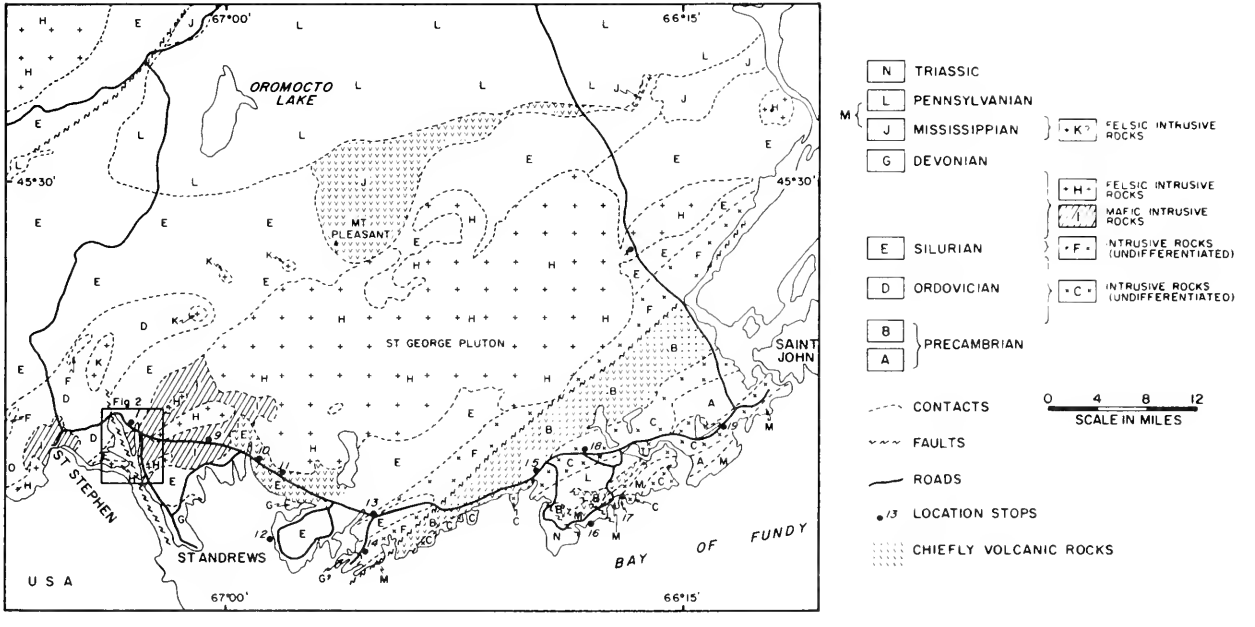


Fig. 1 — Generalized Geological Map of Southwestern New Brunswick.

evidence indicates the existence of Precambrian and Silurian intrusions amongst the older intrusions (Neale and Pajari, 1972; H. Donohoe, oral communication).

LOG AND STOPS

MILEAGE

0 Junction of Highways 1 and 3 in St. Stephen.

9.9 East side of Waweig Bay

STOP 1 The outcrops along Highway 1 represent contact metamorphosed Silurian sediments adjacent to a gabbroic phase of the St. George Pluton.

A zone 100' wide adjacent to the contact is in the pyroxene hornfels facies – the mineral assemblage is quartz, k-feldspar, biotite, plagioclase, cordierite and andalusite. A hornblende hornfels facies assemblage of qtz, k-spar, biotite, plagioclase and muscovite extends for a further 500-1000 feet from the contact. For a distance up to 150 feet from the contact, the bedding has been transposed along vertical shear planes imparting a gneissose appearance to the rock.

Leaving this stop bear right onto Highway # 127 and proceed toward St. Andrews.

10.5 Road cut on east side of road

STOP 2 A grey biotite-hornblende granodiorite intrudes and assimilates brecciated gabbro. The hybrid granodiorite adjacent to the diorite has a mottled appearance caused by the patchy distribution of contrasting grain sizes. The hybrid granodiorite grades into a hypidiomorphic granodiorite typical of the main body of pink hornblende-biotite granodiorite. Figure 3 (Northern Zone) shows the CaO, Na_2O and K_2O compositions of the rocks in this reaction zone.

11.9 Road cut on east side

STOP 3 An ophitic diorite intrudes and is chilled against a hybrid hornblende granodiorite. Southward the ophitic diorite changes gradationally to a melanocratic granodiorite. This type of gradational change from gabbro to granodiorite is a common feature in the zone along the northern edge of the hornblende adamellite intrusion (Fig. 2). The CaO, Na_2O and K_2O compositions of the hybrid rocks formed along this contact are shown in Figure 3 (Southern Zone). A dike of biotite granodiorite cuts the ophitic gabbro.

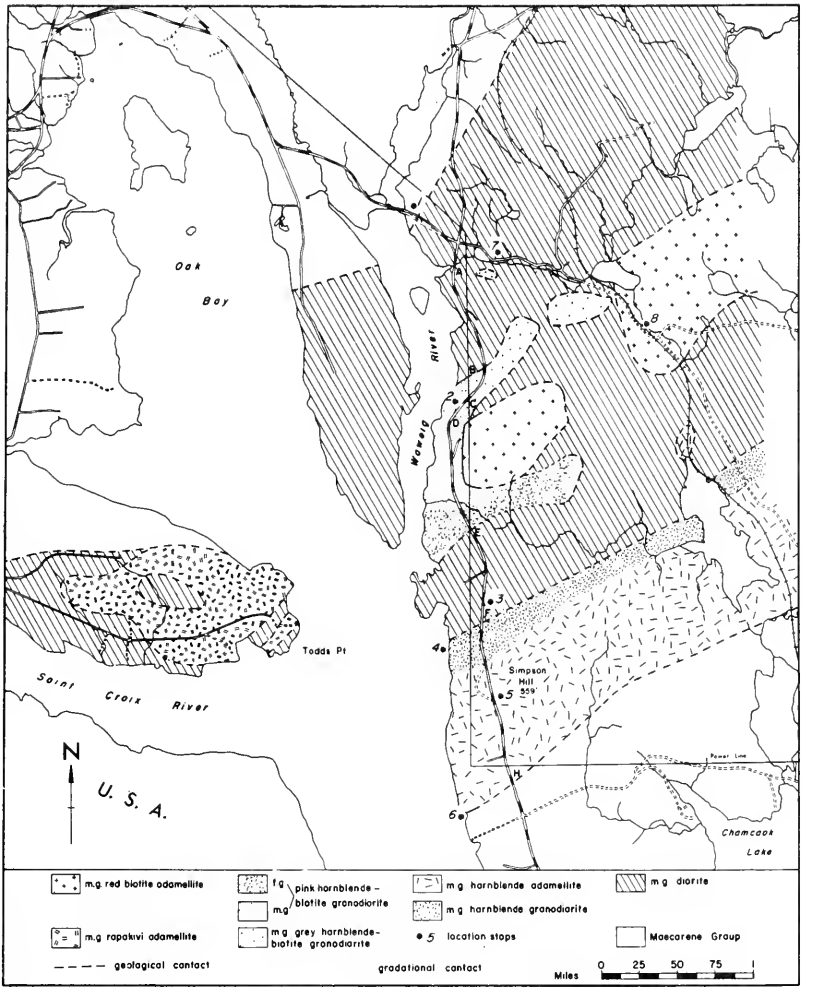


Fig. 2 — Geological Map of the western part of the St. George Pluton (after Fyffe, 1971).

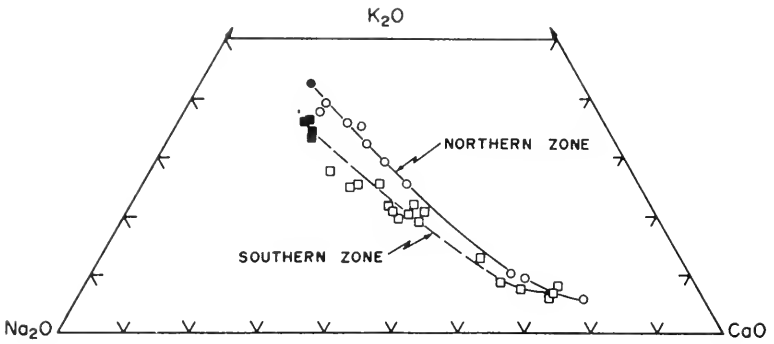


Fig. 3 — CaO-Na_2O-K_2O variation trends of intrusive rocks and hybrids from the northern and southern areas of Figure 2.

Proceed on foot to the shore (600 yds.) along a trail which begins beside the barn on the west side of the road.

STOP 4 The shore exposures (Fig. 4) afford a nearly continuous section across the complex contact zone where assimilation and reaction features that resulted from the intrusion of the hornblende adamellite into ophitic gabbro can be seen in detail.

12.3 Road cut

STOP 5 The outcrop consists of hornblende adamellite containing a small percentage of inclusions of variably digested basic rock. On the east side of the road, disseminated sulphide mineralization containing pyrite, pyrrhotite, chalcopyrite, arsenopyrite and a Ag-sulphosalt occurs adjacent to a small basic dike.

13.1 Turn right (west) onto dirt road to the end (0.3 miles). Walk to shoreline and proceed northward for 1000 feet to the hornblende adamellite contact.

STOP 6 The traverse to the contact is along gently folded sedimentary and igneous rocks of lower Devonian age (Boucot et al, 1966). The rocks up to 20 feet from the adamellite intrusion have not been noticeably disturbed nor metamorphosed by the intrusion. Return to cars and drive to St. Andrews for the night.

SECOND DAY

Proceed to the junction of Highways 1 and 127 at Waweig Bay and turn right (east) on Highway 1 (mile 0.0).

0.2 Road cut on left side of road.

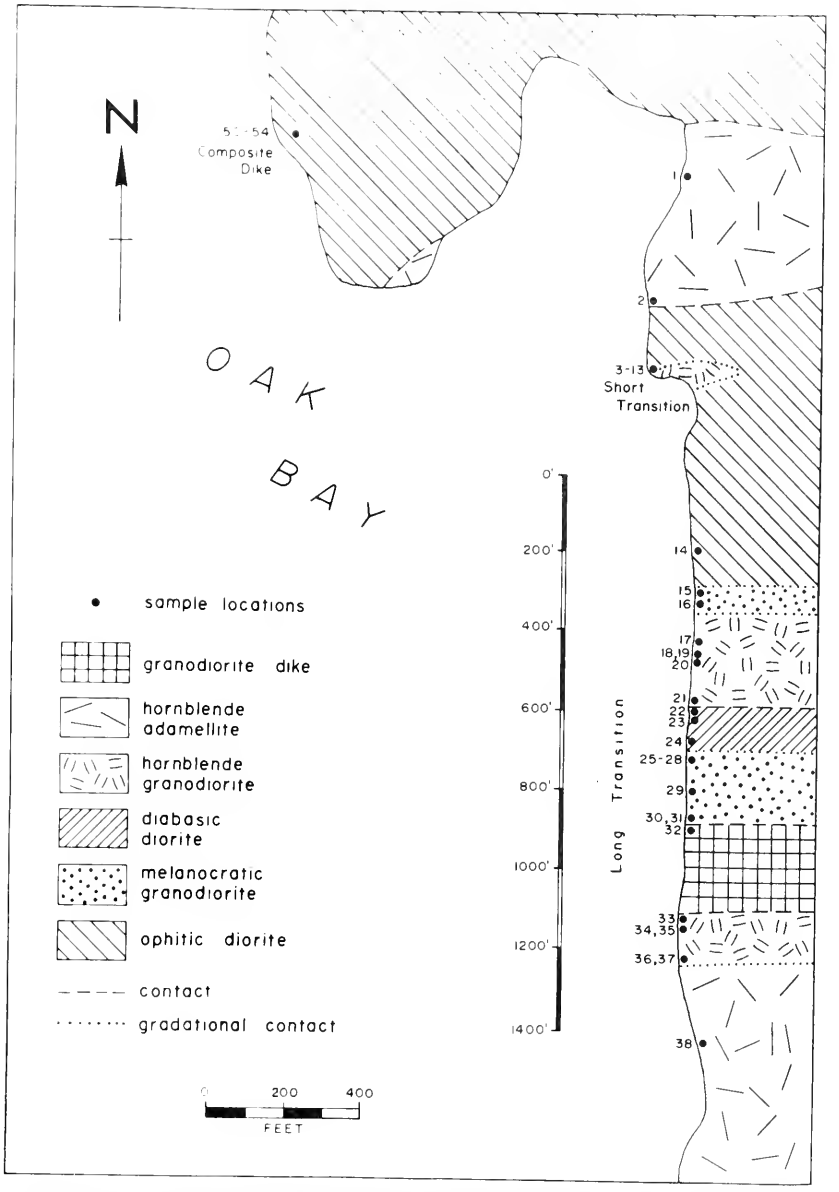


Fig. 4 — Geological Map of the contact zone between gabbro (diorite) and a younger adamellite (after Fyffe, 1971).

STOP 7 The ophitic gabbro is veined by white tonalite. This veining is a characteristic feature of the gabbro in areas adjacent to the northern felsic intrusions (Fig. 2). The composition of the tonalite does not plot on the curve for the northern zone rocks on Figure 3.

1.3 Rock cuts on left (north) side of road.

STOP 8 The red biotite adamellite was considered by Fyffe (1971) to be the youngest felsic intrusion within the area of Figure 2. It is distinctly more potassic than any of the other felsic intrusions in this area. Several narrow basic dikes cut this unit.

6.3 Road cut.

STOP 9 Poorly defined layering, dipping gently to the west, can be observed in the ophitic gabbro. Some of the layers have a well developed primary mineral foliation parallel to the layering.

10.2 Road cut.

STOP 10 This outcrop consists of flow layered and brecciated rhyolite of Upper Silurian age (Hay, 1967). The area between the coast and the St. George Pluton consists largely of basalt and rhyolite dipping consistently 20-30° toward the southwest. The stratigraphic thickness of these volcanics is about 5000 feet (Hay, 1967).

12.4 Turn left onto Roix Road. Proceed 0.6 miles to the microwave tower road (steel gate). Proceed 500 yards along road.

STOP 11 Silurian volcanic rocks are intruded by a micro-adamellite. The adamellite is in turn intruded by diabase dikes and coarse-grained granite. This granite is typical of the rock composing the southern half of the St. George Pluton. Proceed back to Highway 1.

15.8 Take right hand exit road into St. George. Proceed to Letete via Back Bay on Highway 772. Turn right and continue northward 1.5 miles from Letete. Turn left onto a private road and continue to end (0.3 miles).

STOP 12 Lower Devonian (Gedennian) sediments are intruded by an aphanitic felsic body showing typical high level intrusive characteristics. The sedimentary rocks possess a cleavage which

has been folded by the second Acadian deformation. Return to St. George and Highway 1 via the eastern exit.

0 Junction Highway 1.

1.5 Rock cut on north side of road.

STOP 13 Numerous basic dikes intrude granite of Unit F (Fig. 1). This granite contains an inclusion of tuff believed to be of Silurian age (H. Donohoe, oral communication, 1973).

2.7 Turn to the right and proceed to Black's Harbour (4 mi.) Stop at prominent hill on east side of road 1000 feet into the village.

STOP 14 The Black's Harbour granite is unconformably overlain by a red conglomerate. Both are intruded by a diabase dike in which the plagioclase phenocrysts are concentrated along the middle of the dike (flowage differentiation). Return to Highway; turn to right (east) and resume mileage.

15.1 Low outcrop on north side of road.

STOP 15 A basic dike which is chilled against felsic rock and is intruded by the same felsic rock. Rast (oral communication, 1973) has suggested that the dike may have mobilized the felsic material during intrusion.

17.8 Turn right onto Highway 790 and proceed to Dipper Harbour. At Dipper Harbour bear left to encircle the Harbour. Two miles from Dipper Harbour, extensive shore line outcrops occur several hundred feet from the road.

STOP 16 The rock is an ash-flow tuff which possesses an eutaxitic structure. The sedimentary rocks associated with these tuffs have been correlated with the Carboniferous Mispec Formation at Saint John.

Proceed eastward toward Little Dipper Harbour on Highway 790. One half mile east of the turnoff to Little Dipper Harbour turn right onto unimproved road. Stop at sand beach 0.7 miles from intersection.

STOP 17 The Carboniferous sedimentary rocks can be observed to have been subjected to two periods of deformation (see Rast and Grant, this guidebook). The older granites north of the road and across the cove have been thrust over the sediments along a nearly horizontal plane which is about 40 feet above sea level at this location.

Return to Highway 790, turn to the right and proceed for 3 miles. At the intersection, turn left and continue to the junction with Highway 1. Turn right (toward east).

0 Junction Highway 1.

0.5 Road cut on north side of road.

STOP 18 The fresh adamellite at this location is identical to ones in the St. George Pluton and have therefore, been tentatively correlated with the St. George intrusive event.

9.8 Large road cut on the south side of Highway 1 along the road under construction.

STOP 19 The deformed and altered igneous rocks in this outcrop are a part of a thrust sheet which has over-ridden Carboniferous rocks exposed at the east end of the lake across Highway 1 (see Rast and Grant, this guidebook).

The heterogeneity of the rock compositions observed in this exposure is typical of the deformed intrusions.

Trip A-4, by H. W. van de Poll, University of New Brunswick

CARBONIFEROUS STRATIGRAPHY AND SEDIMENTOLOGY OF THE CHIGNECTO BAY AREA: SOUTHERN NEW BRUNSWICK

INTRODUCTION

The purpose of this field excursion is to examine the vertical and lateral facies transitions from an upper Mississippian marine evaporite succession (Windsor Group) to a lower Pennsylvanian continental fluvio-paludal sequence (Cumberland Group) and to reconstruct the apparent tectonic palaeo-physiographic and climatic conditions under which the transition has taken place. Copper, silver, vanadium, mercury and to a lesser extent lead, of the so-called "sedimentary" type are widely associated with these strata.

A brief discussion of the Carboniferous geology of the Maritime Province is presented here to emphasize the evolutionary history of the basin and its stratigraphy.

PREVIOUS WORK

The first geological map of New Brunswick was published by James Robb in 1849-50, and shortly after, the Carboniferous subdivisions appeared in their proper stratigraphic order when Sir William Dawson issued his first edition of "Acadian Geology" in 1885. Following the passage of the Confederation Act in 1867, the Geological Survey of Canada expanded its geological coverage to the Maritime Provinces.

The most important advances in the local Carboniferous stratigraphy, however, were not made until after the turn of the century as a result of the palaeobotanical studies by W. A. Bell of the Geological Survey of Canada. Bell, until his death in 1968, devoted more than 50 years to geological work in the Maritimes. He introduced the present Carboniferous stratigraphic subdivisions and correlated them with those of the United States and Europe. In 1914, Marie Stopes published her classic work on the flora of the Saint John "Fern Ledges" and demonstrated their striking similarity with the Westphalian flora of the European coal measures.

Subsequent regional palynological studies by P. A. Hacquebard, S. Barss and D. Donaldson of the Geological Survey of Canada were particularly successful in assigning otherwise non-

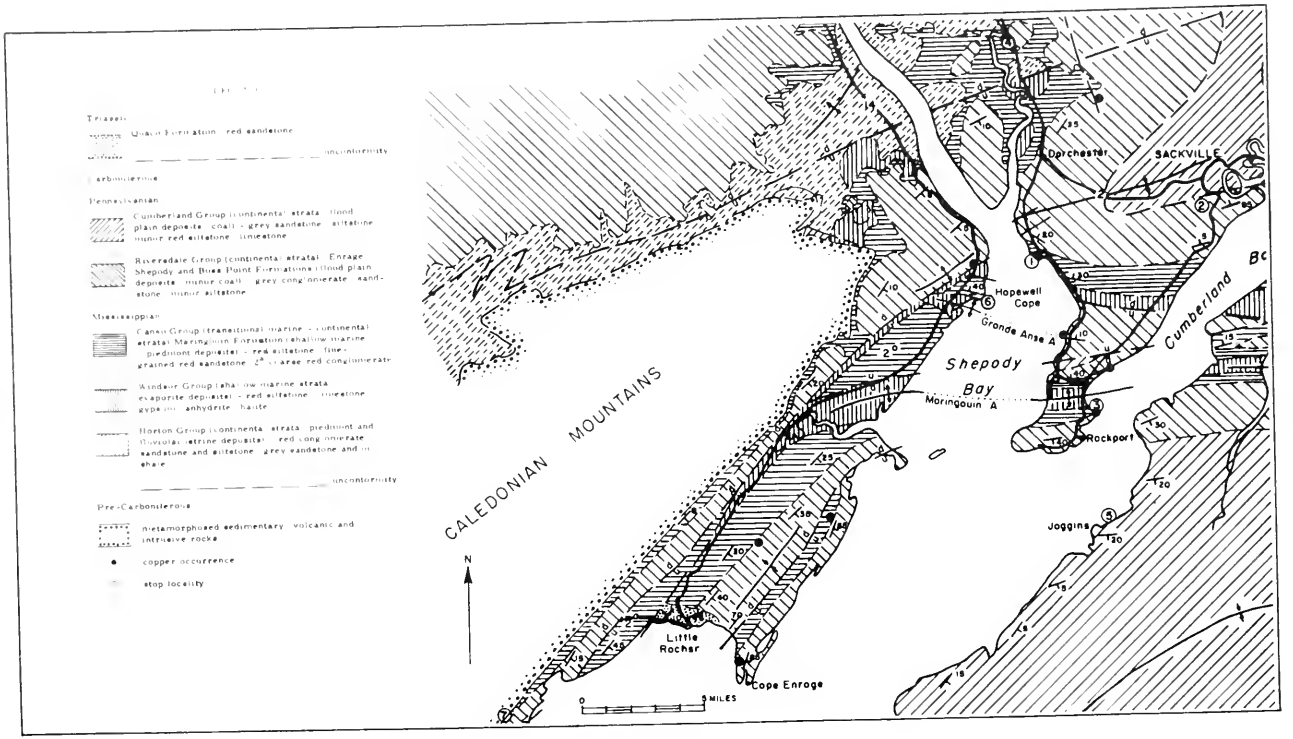


Fig. 1 Geology of the Chipucto Bay Area, N. B.

fossiliferous Carboniferous sequences to their proper stratigraphic position, and led to important modifcations of the Pennsylvanian stratigraphy.

THE DEPOSITIONAL BASIN

The term "Acadian Orogeny" as used here refers to the orogenic event during which the Appalachian Geosyncline was subjected to folding and faulting, intruded by granitic batholiths, became uplifted and was subjected to erosion by Middle Devonian times. In contrast to pre-Acadian rocks, which are mainly marine turbidites and associated volcanic rocks (flysch), post-Acadian strata are predominantly terrestrial red and grey beds in which plant fragments are common (molasse).

Early, post-Acadian deposition of molasse type sediments became firmly established by Middle Devonian time (Hacquebard, 1971) and initially was probably confined to partly connected basins.

Continued subsidence and concomittant onlap of sediments onto the surrounding foreland areas during the Carboniferous and Permian gradually consolidated to original loci of deposition into a large successor basin, of which the remains still underlie parts or all of Newfoundland, Nova Scotia, New Brunswick, Prince Edward Island, Quebec and the Gulf of St. Lawrence. The present total area of (post-Acadian) Devonian and Permo-Carboniferous strata is approximately 65,000 square miles, of which an estimated 25,000 square miles is on land (Kelley, 1967).

The destructive phase in the evolution of the basin did not take place until post-Permian times, and perhaps may not have taken place until post-Triassic times when all of the region became uplifted and subject to erosion.

The present outline of the basin therefore is the result of erosion rather than deposition. Although the original palaeogeography of the basin is not known, recent sedimentological work has shown that the present western margin of the basin in Southwestern New Brunswick was once covered by up to several thousand feet of Permo-Pennsylvanian strata (van de Poll, 1970).

Three main categories of deformed Carboniferous strata can be identified. These are:

(a.) open and closed folds, locally associated with slaty cleavage;

(b.) tilted and locally overturned strata on the flanks of salt-cored piercement anticlines, and

(c.) tilted and locally overturned strata occurring in association with post-Carboniferous faults.

Slaty cleavage is locally developed, notably in the so-called "Fern Ledges" (Westphalian B age) of the Saint John Harbour area and to a lesser extent also occurs in lower Mississippian strata of the Canso Strait area of Nova Scotia. These comprise the most extensively deformed rocks of the basin although the nature of the deformation and its significance in the tectonic development of the basin are poorly understood.

The most common type of deformed strata are tilted beds on the flanks of salt-cored piercement anticlines where dips ranging from sub-horizontal on the margin to vertical or steeply overturned in the axial regions of these structures may be observed.

Tilted and locally overturned strata associated with high angle normal or thrust faults occur subparallel to the prevailing northeasterly and easterly structural trend of the basin. These faults are of major proportions and in most instances can be traced over considerable distances into pre-Carboniferous basement rocks. The main period of post-Carboniferous fault displacement took place probably between early Permian and Triassic times (van de Poll, 1970).

STRATIGRAPHY

The Carboniferous succession of Atlantic Canada is subdivided into six major stratigarphic units as follows:

Pictou group	Westphalian C – lower Permian
Cumberland group	Westphalian A – B
Riversdale group	Namurian C – Westphalian A
Canso group	Upper Viséan – Namurian
Windsor group	Viséan
Horton group	Upper Devonian – Tournaisian
– – – – – – –	Major Unconformity
Metamorphic	Basement Complex

Horton Group – The Horton Group comprises a succession of red and grey conglomerate, sandstone and siltstone locally with intercalations of volcanic rocks. The sequence overlies pre-Carboniferous basement with a pronounced angular unconformity and conformably underlies basal limestone of the Windsor

Group. In Southeastern New Brunswick the Horton Group includes lacustrine oil shales containing plant and fish remains.

Horton strata were originally designated by their characteristic lower Mississippian (Tournaisian) flora but more recently the age limits of the group have been extended from late Early Devonian to Viséan (Hacquebard, 1971). According to Bell (1960), the Horton flora appears of approximately the same age as the Pocono flora of the Appalachian region of the United States.

Windsor Group — The Windsor Group is the only known marine sequence in the Carboniferous section of Atlantic Canada and has been subdivided on lithological and faunal evidence into two zones and five subzones.

Each subzone is characterized by a cyclic repetition of strata involving a basal limestone overlain by red lutite, an evaporite sequence and again red lutite. In ascending order the subzones are designated as subzones A B, C, D and E and as originally defined by Bell (1929) each subzone was regarded as a chronostratigraphic unit containing a restricted suite of fossils.

More recently, however, it has been suggested (Schenk, 1967) that the Windsor subzones represent repeated wedges of marine transgressions. In his facies model Schenk (1967) proposed that each marine incursion is characterized by a carbonate zone, representing offshore and lagoonal conditions which terminate landwards against a lutite-evaporite succession of intertidal and/or salt-flat origin. The lutite-evaporite succession in turn is interpreted to be followed at its distal end by a continental red alluvial fan, or fanglomerate.

Windsor strata in Southern New Brunswick demarcate the western limit of the marine transgression and are represented by subzones A, B and the lower part of C (Gussow, 1953). They are conformably overlain by redbeds of the Canso Group (Maringouin Formation in New Brunswick) which are equivalent to Windsor subzones D and E in Nova Scotia.

Canso Group — The Canso Group represents the facies transition from marine to continental sedimentation and lies stratigraphically between the marine strata of the Windsor Group and the fluvial continental beds of the Riversdale Group.

The Canso Group is primarily characterized by red lutites in which small-scale primary sedimentary structures predominate. The unit grades laterally into marginal conglomerates of near-

source derivation and closely resembles a marine regression bahada-playa sequence expanding in the wake of the retreating Windsor sea towards the east.

Riversdale Group – As originally defined (Bell, 1944), the Riversdale Group was primarily distinguished by its Westphalian "A" flora except in the type section in Nova Scotia which is unfossiliferous (Kelley, 1967). Subsequent work, however, has shown the Riversdale type section to include time equivalent strata to the Canso Group (Hacquebard, 1971). As a result it has become desirable to redefine the Riversdale Group (Kelley, 1967) and to restrict the term to a sequence of mainly grey fluvial strata in which plant fragments are common, lying above the bahada-playa succession of the Canso Group and below the fluvio-lacustrine coal measures of the Cumberland Group.

The expanded Riversdale Group now includes, in addition to the Enragé and Boss Point Formations, the Shepody Formation, which was previously assigned to the Canso Group, and is subdivided as follows:

Boss Point Formation – mainly grey fluvial sandstone, subordinate red siltstone (floodplain type), basal quartz pebble conglomerate (rounded clasts), plant fragments very common.

Enragé Formation – red siltstone (transitional floodplain-playa type) and red and grey fluvial sandstone, basal quartz-pebble conglomerate (sub-rounded clasts), few plant fragments.

Shepody Formation – grey fluvial sandstone and interbedded red siltstone (playa type), plant fragments locally common.

The lower contact of the Shepody Formation is characterized by the first appearance of grey or red fluvial sandstone (conglomerate) overlying playa red siltstone (sandstone or fanglomerate) of the Canso Group.

In contrast to the subangular, poorly-sorted Canso conglomerates, the Riversdale conglomerates are characterized by a predominance of stable components (quartz and quartzite), better sorting and roundness of the clasts.

Cumberland Group – Rocks of the Cumberland Group overlie Riversdale strata conformably and include the Joggins section in western Nova Scotia. The succession consists of red and grey sandstone, siltstone, minor grey limestone and includes the well known coal seams of Springhill and Joggins.

Cumberland strata were previously thought to be unconformably overlain by, or in faulted contact with, strata of the younger Pictou Group, but more recent work has indicated the presence of a conformable transition of strata throughout the Westphalian time period.

Nevertheless, Cumberland strata have only been identified in western Nova Scotia and possibly southeastern New Brunswick, where over 9,000 feet is represented in a continuous section along the eastern shore of Chignecto Bay. Elsewhere, however, Cumberland strata appear non-existent indicating localized accelerated subsidence north of the Cobequid Mountains that resulted in a period of non-deposition in the peripheral areas.

Pictou Group – The name Pictou Group (Bell, 1944) applies to a non-marine succession of alternating red and grey sandstone and siltstone, grey-green siltstone and coal lying stratigraphically above the Cumberland Group. As originally defined, the Pictou Group was considered the youngest Carboniferous time stratigraphic unit containing a characteristic Westphalian C and D flora. Subsequent work, however, (Barss and Hacquebard, 1967; Kelley, 1967) has shown the time limits of the Pictou Group to range from lowermost Westphalian C to lower Permian.

In New Brunswick the total Pictou succession can be subdivided into 3-1/2 megacycles, each several hundreds of feet thick. Each cyclic sequence comprises a lower grey conglomerate-sandstone facies sequence overlain by a finer grained red sandstone-siltstone facies sequence. Coal, in association with grey-green siltstone, is locally present at the transition interval from the grey to red facies sequences.

LOG AND DIRECTIONS

STOP 1 – Dorchester Cape, Windsor, Canso and Riversdale strata are exposed in the shore section of Dorchester Cape and Grande Anse. The succession lies on the northern flank of the Grande Anse Anticline and dips to the north-northeast at approximately 25°.

The base of the section is made up of orange-red siltstone of the Windsor group and includes an 18-inch bed of gypsum. Although subzone C limestone has not been identified, the sequence has previously been assigned on general stratigraphic principle to the top of subzone B (Gussow, 1953).

The contact between the Windsor and Canso strata is transi-

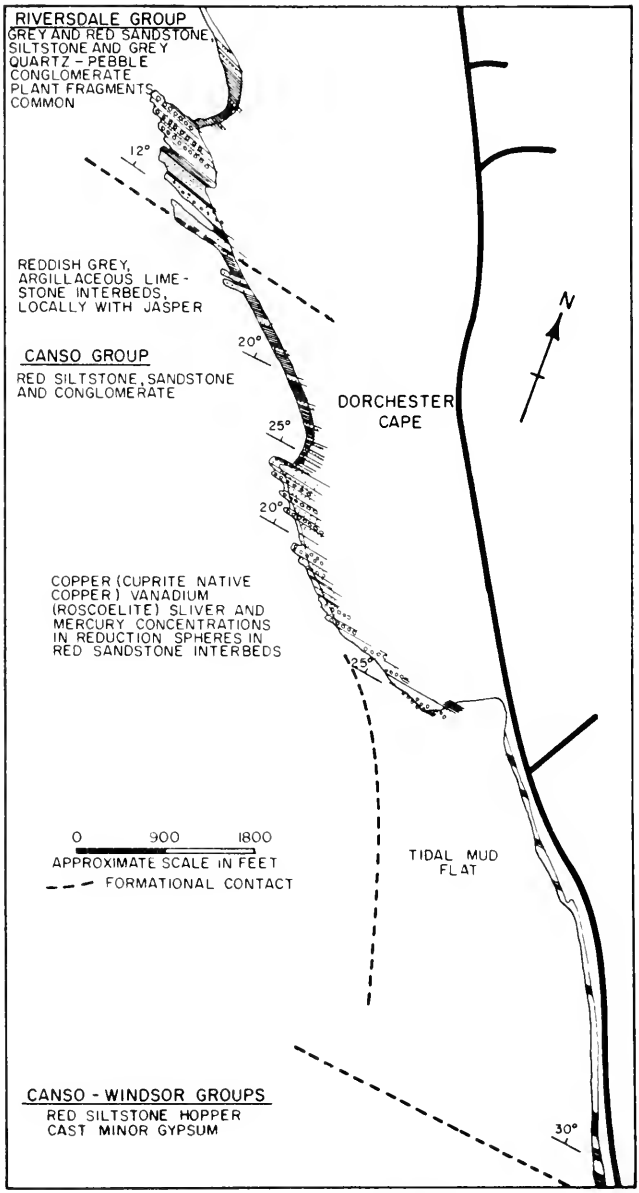


Fig. 2 Geological Section, Dorchester Cape, N. B. (stop locality 1)

tional and in the absence of Windsor limestone cannot be clearly defined. The lower part of the Canso Group comprises a coarsening upwards sequence and at Dorchester Cape is a cyclic succession of red conglomerate, sandstone and fine-grained red sandstone. The upper part of the Canso Group reverses to a fining upward sequence in which orange-red siltstone predominates. Several beds of nodular, and argillaceous greyish-red limestone with associated jasper occur near the top of the sequence. The Canso Group is interpreted to represent a salt flat-playa lake succession that includes a fan-toe wedge of an alluvial fan spreading from the north across the playa. Small concentrations of copper (malachite, cuprite, native copper), vanadium (roscoelite), silver and mercury (Sutherland, 1972), occur widespread with the conglomerate-sandstone sequence at Dorchester Cape. They form dark centres, up to 1/2 inch diameter in so-called "bull's eyes" or reduction spheres and appear particularly common in the cyclically recurring fine-grained sandstone interbeds.

Grey and red fluvial sandstone of the Riversdale group overlies strata of the Canso Group conformably. Although reversals to red siltstone are common, in particular near the base, the sequence exhibits an overall coarsening upwards tendency with frequent recurrences of extrabasinal quartz-pebble conglomerates, in particular at the base of the Boss Point Formation.

The characteristically mature composition and relatively high degree of roundness of the Boss Point conglomerates with respect to those of the Canso is interpreted to reflect a major change in the development of the basin. A transition from nearby to distal sources and concomitant widespread onlap of Pennsylvanian strata accompanied this change resulting in the gradual and complete transgression of all intrabasinal basement ridges in southern New Brunswick and western Nova Scotia such as the Cobequid and Caledonia Mountains, the Westmorland uplift and the Minto-Chipman basement ridge.

STOP 2 – Rock quarry, British Settlement. Vertical to steeply overturned Boss Point strata are exposed in the quarry. The sequence is characterized by medium-grained cross-bedded grey sandstone and minor dark siltstone. Large plant fragments are common. The succession is overlain by mottled grey and red quartzitic sandstone of the Cumberland group.

STOP 3 – Pecks Point, Cape Maringouin. The cliffed shore from Pecks Cove to Ward Point displays a continuous and conformable sequence of Canso-Riversdale strata and exemplifies the facies transition from a shallow marine salt flat-playa environment to a

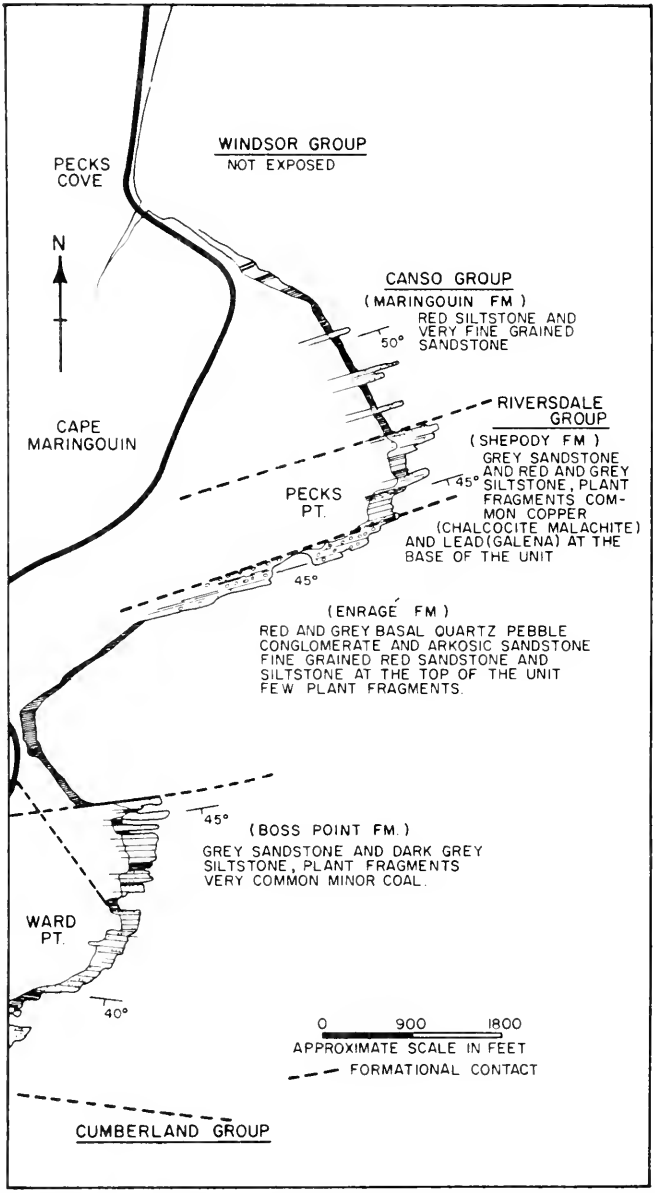


Fig. 3 Geological section, Pecks Cove to Ward Point, Cape Maringouin, N. B. (stop locality 3)

continental flood plain environment of deposition. The succession lies on the southern flank of the Maringouin (piercement) anticline and dips to the south-southeast at an average of 40°.

The Windsor Group, although not exposed in the section, is known from exposures on strike on the western shore of Cape Maringouin to include limestone, red siltstone and gypsum. The limestone is assigned to subzone C (Bell, 1944), and overlies the red siltstone-evaporite succession of subzone B.

Canso strata in the section are characterized by orange-red siltstone with fine-grained red sandstone interbeds. The succession becomes more sandy towards its upper contact, and the predominance of ripple drift gradually gives way to small-scale crossbedding and parting lineations.

The succession is interpreted to reflect the introduction of a large sediment supply in a low energy environment of deposition and is attributed to playa-coastal mudflat sedimentation.

The base of the Riversdale sequence is set at the lower contact of massive grey channel sandstone unit with a channel-lag mud-pellet conglomerate at the base. Plant fragments with concentrations of copper (chalcocite, malachite) and lead (galena) are common near the base of this unit. Regional stratigraphic work has shown that copper (chalcocite, malachite), silver and to a minor extent galena are widely concentrated at or near the base of the Riversdale.

STOP 4 – Gravel quarry, College Bridge. The quarry strata are made up of horizontal, poorly consolidated, thick bedded basal conglomerates of the Boss Point Formation. The characteristically mature composition (quartz, quartzite, jasper, chert, rhyolite and relatively high degree of roundness (Rho factors up to 70%)) of the clasts are well displayed and attest to the distal, extrabasinal fluvial origin of these strata.

STOP 5 – Joggins (stop co-leader: Dr. L. Ferguson). The Joggins shore section lies on the southern limb of the Maringouin Anticline (Minudie Anticline in Nova Scotia) and offers a unique view of vertical facies variations in the lower Pennsylvanian coal measures Cumberland Group. The Cumberland Group conformably overlies grey sandstone of the Boss Point Formation, and grade upwards into strata of the Pictou Group. The sequence is of non-marine origin and, as originally mapped by Logan (1845), Dawson (1878) and modified by Shaw (1951), contained five principal coarse and fine interfingering clastic units. From an

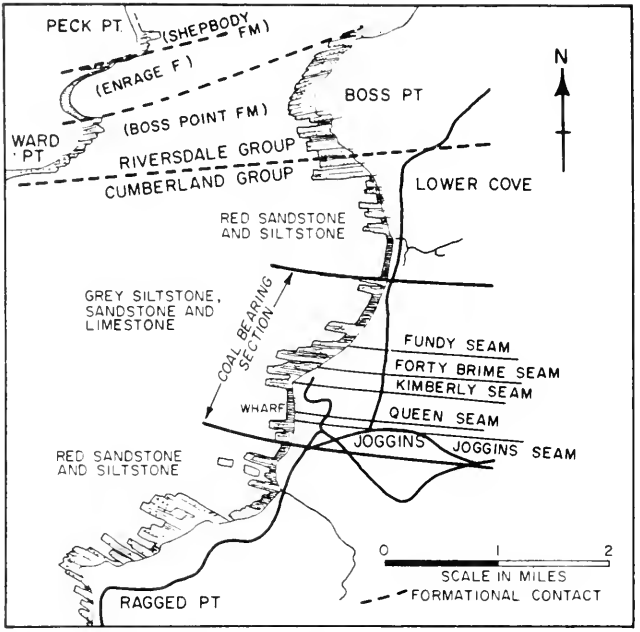


Fig. 4 Geological section of Joggins from Boss Point to Ragged Point, N. S. (stop locality 5). (Geology modified after Shaw, 1951)

economic point of view the most significant unit is the middle, fine-grained, coal bearing facies which is exposed in the Joggins area see "Coal Bearing Section" Fig. 4). This unit is characterized by cyclic recurrences of beds exhibiting the following sequence of deposition:

7) interbedded grey sandstone and shale,

6) grey shale, locally with plant remains,

5) black carbonaceous shale containing ostracods and pelecypods,

4) grey to black highly calcareous shale containing ostracods and pelecypods,

3) coal,

2) underclay with *stigmariae*,

1) grey sandstone containing comminuted plant remains.

Incomplete cycles are common, and the stratigraphic interval that each cycle occupies may range from a few inches to several tens of feet (Copeland, 1957). Most spectacular were the fossilized trees standing upright in the massive sandstone. However, rapid erosion of the coast has removed the best exposures although a few tree trunks are usually still visible.

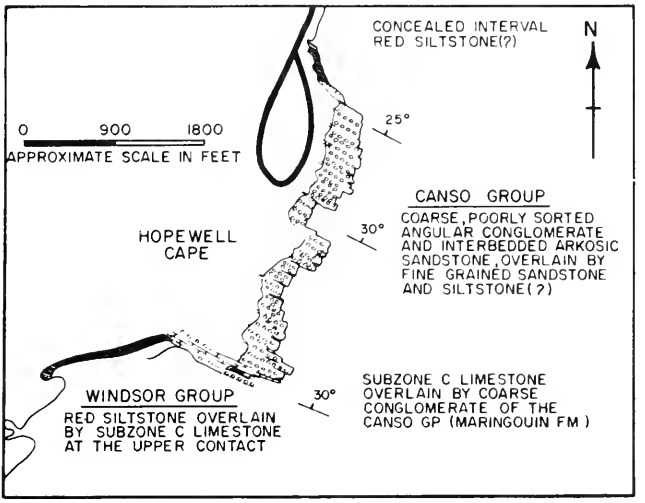


Fig. 5 Geological section of Hopewell Cape, N. B. (stop locality 6)

STOP 6 – Hopewell Cape. Dark grey fossiliferous limestone of subzone C lies at the base of the section at Hopewell Cape where it underlies and is intercalated with coarse conglomerate of the Canso Group.

The succession lies on the northern flank of the Grande Anse Anticline and dips to the north-northwest at approximately 25°. In contrast to playa type silt and fine-grained sandstone, which characterized the Canso Group elsewhere in the Shepody Bay region (e. g. at Pecks Cove, Stop Locality 2), the Hopewell Cape sequence is mainly coarse, poorly sorted conglomerates and arkosic sandstone in which sub-angular clasts of granite, gneiss, and volcanic rocks predominate. The succession is interpreted to represent a high-energy fan-head or mid-fan deposit of an alluvial-fan spreading easterly from a nearby source area in the Caledonia Mountains in the wake of the retreating Windsor sea.

TRIP A-5, by Herwart Helmstaedt, McGill University.

STRUCTURAL GEOLOGY OF THE BATHURST-NEWCASTLE DISTRICT

INTRODUCTION

The Bathurst-Newcastle district is composed of three regional structural units (Smith and Skinner, 1958):

(1) The Ordovician Folded Belt (including the highly deformed and regionally metamorphosed rocks of the Early to Middle Ordovician Tetagouche Group).

(2) The Silurian Folded Belt (corresponds to the Silurian-Devonian Folded Belt (Davies, 1966) and includes the Middle to Upper Silurian and Lower Devonian rocks north of the Ordovician Folded Belt).

(3) The Pennsylvanian Cover (flat-lying red beds of Carboniferous age that unconformably overlie all older strata).

This field trip is concerned with the structural evolution of the oldest unit, the Ordovician Folded Belt (Fig. 1), an area of approximately 1600 square miles corresponding to the northeastern end of the Miramichi geanticline of Poole (1967). The structural information conveyed in this guide is based on mapping of four areas by the present author (Fig. 1, 3: Table 1).

STRATIGRAPHY

The area is underlain by the Early to Middle Ordovician Tetagouche Group. The stratigraphic sequence adopted here (Helmstaedt, 1971, Helmstaedt and Skinner, in preparation) differs from previous lithologic subdivisions by distinguishing two sedimentary units, one at the base of the Tetagouche Group and predating the volcanic sequence, and the other interlayered with and overlying the volcanic rocks and partially derived from them (Fig. 2). The lower sedimentary sequence is characterized by light-colored arenaceous rocks ranging in composition from orthoquartzite to lithic and arkosic sandstones and feldspathic greywacke, all of which are interlayered with grey-colored slates. These relatively mature sedimentary rocks represent the substratum of the volcanogenic part of the Tetagouche Group and are correlated with Early to Early Middle Ordovician quartzites from Central New Brunswick (Poole, 1963) (Fig. 2). The volcanogenic sequence begins with acidic pyroclastics ("porphyries") and

large volumes of rhyolitic rocks. Two major centers of rhyolitic volcanism can be distinguished (Fig. 1). Some intermediate to basic volcanics are interlayered with the rhyolitic rocks, but most basic rocks overly the rhyolitic volcanics. The volcanic pile is

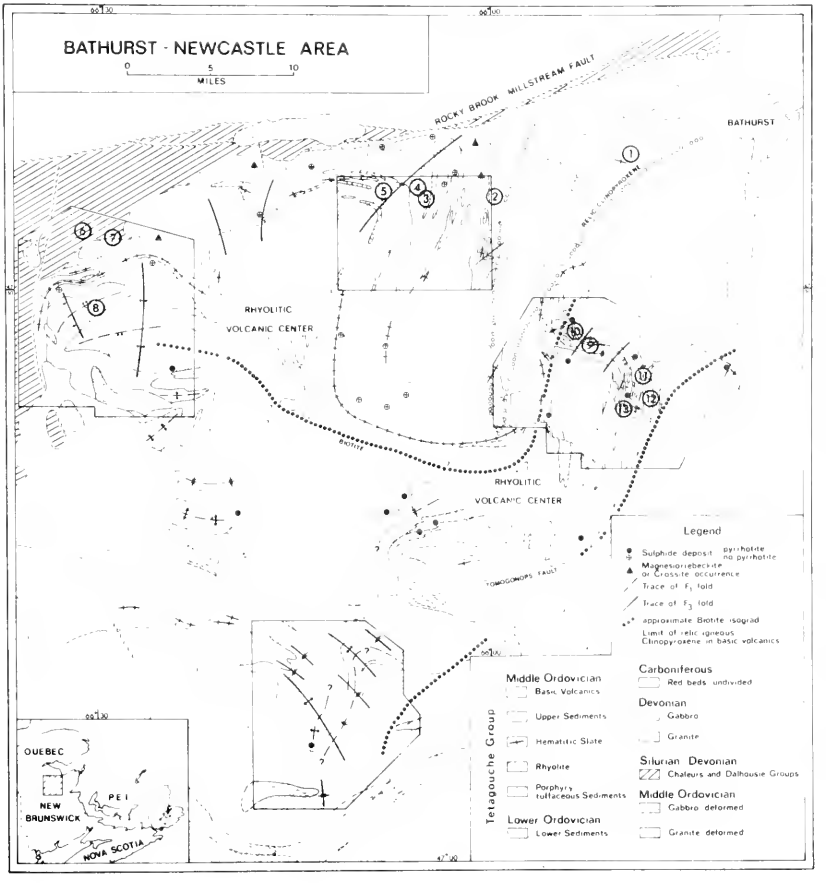


Fig. 1 Structural compilation map of Bathurst-Newcastle district by Helmstaedt and Skinner (manuscript in preparation). Areas outlined (see also Figure 3) are after Helmstaedt (1970, 1971, in press). Geology of Brunswick Mines area (Area III) modified after Boyle and Davies (1964), Stockwell and Tupper (1966) and D. Rutledge (unpublished maps). Remainder of the area modified after Davies (1968) and published maps of the New Brunswick Mineral Resources Branch and the Geological Survey of Canada.
Blank areas: no firsthand structural information.
Encircled numbers correspond to field trip stops in road log.

Table I Table of Fabric elements in four areas of Bathurst-Newcastle district, N. B.

Phase of Def.	Fabric element	Area I: Head of Middle River and Wildcat Brook	Area II: Portage Lakes Area	Area III: Brunswick Mines Area	Area IV: Clearwater Area
	Primary Structures	Locally bedding (S_0), amygdules, pillow structures	Locally bedding (S_0)	Locally bedding (S_0) graded bedding, crossed bedding, local sole marks, possible pre-lithification slumping	Bedding (S_0) graded bedding very rarely preserved
First (D_1)	Planar Fabric (S_1)	Regional foliation: penetrative steep schistosity, phyllitic cleavage, slaty cleavage, caused by parallel alignment of phyllosilicates, flattened porphyroclasts, fragments, amygdules	Regional foliation: penetrative (except in massive greenstones) moderate to steep (otherwise like Area I)	Regional foliation: penetrative, steep (otherwise like Area I)	Foliation: penetrative, original orientation probably steep, in many instances transposed along S_2
	Linear Fabric (L_1)	Mineral Lineation: penetrative, steep linear alignment of longer dimensions of porphyroclasts and lenticular fragments, trails of phyllosilicates, and in places C-axes of amphiboles. Rodding of quartz veins. In sediments intersection of S_1 and S_0	Mineral lineation: less common than in Area I, original orientation probably steep (otherwise like Area I) In sediments intersections of S_1 and S_0	Mineral lineation: locally strongly developed, generally steeper (otherwise like Area I) In sediments intersections of S_1 and S_0	Mineral lineation: rarely seen, local rodding of quartz veins In sediments intersections of S_1 and S_0
	Folds (F_1)	Isoclinal to subisoclinal folds: microscopic and mesoscopic: macroscopic folds not recognized. Axes steep (parallel L_1), mostly intrafolial folds	Tight to isoclinal folds: mesoscopic and macroscopic	Tight to isoclinal folds: microscopic, mesoscopic, macroscopic axial planes steep, plunge moderate to steep.	Tight to isoclinal folds: mesoscopic (mostly intrafolial) macroscopic.
	Faults	?	possible low angle thrusting	low angle thrusts	?
Post-D_1				local crenulation, steep axial planes	
Second (D_2)	Planar Fabric (S_2)	Crenulation cleavage / Fracture cleavage — less penetrative than S_1 moderately steep to shallow	Crenulation cleavage: penetrative, shallow to horizontal (more penetrative and stronger developed than in Area I)	Crenulation cleavage / Fracture cleavage } penetrative in schistose rocks, steep to moderate	Schistosity / Crenulation-cleavage — very penetrative, in many places major plane of anisotropy, shallow to horizontal

	Linear Fabric (L_2)	Axes of crenulations, normally observed on S_1, intersection of S_1 and S_2	Axes of crenulations, intersections of S_2 and S_1 and S_2 and S_0	Axes of crenulations, intersections of S_2 and S_1, S_2 and S_0	Axes of crenulations (mostly obliterated by D_3) intersections S_2 and S_1
	Folds (F_2)	Mostly asymmetric tight to open crenulations, some chevron folds: microscopic, mesoscopic, locally macroscopic. Axes moderate to shallow	Crenulations: microscopic mesoscopic recumbent, shallow to horizontal axes	Crenulations: tight to open, mesoscopic	Crenulations: isoclinal to open, microscopic, mesoscopic recumbent
	Faults	?	?	small lateral offsets along S_2	?
Third (D_3)	Planar Fabric (S_3)	No penetrative cleavage, local joints and tension gashes	Crenulation cleavage / Fracture cleavage } locally developed, vertical	No penetrative cleavage	Crenulation cleavage: penetrative in schistose rocks, steep to vertical
	Linear Fabric (L_3)	Axes of kink folds	Axes of fine crenulations mainly on S_2 but also on S_1	Axes of kink bands (shallow and steep	Axes of crenulations: very penetrative (on S_2)
	Folds (F_3)	Local kink folds, asymmetric and conjugate sets. Large regional fold (Tetagouche antiform), steep axis	Kinks, chevron folds, open folds, microscopic mesoscopic, macroscopic shallow axes	Kink bands (shallow and steep sets) age relationships not known, mesoscopic, regional folding, steep axes	Crenulations: tight to open microscopic mesoscopic, macroscopic, upright, horizontal axes. A-C joints connected with mesoscopic folds.
	Faults	?	faults associated with upwarping	? faulting with relatively large horizontal slip components	?
Post-D_3*		Faults and various joint sets, may in part be caused by D_3	Faulting (?)	Faulting (i.e. lateral offsets of late dykes)	
Fourth (D_4)	Planar Fabric (S_4)				Fracture and crenulation cleavage, steep, very local
	Linear Fabric (L_4)				Local crenulation, intersection of S_4 and older S-planes
	Folds				Local open folds upright, mesoscopic
	Faults				?East-West faults (Tomogonop fault)
Post-D_4					Faulting (could be related to D_4), or later

* Post-D_3 in Areas I, II and III may be later than D_4 of Area IV.

thickest in the center of the district and thins towards the margins (Fig. 2). In the northeastern part the abundance of rhyolitic rocks decreases and the main volume of volcanics consists of basic rocks interlayered with greywackes and slates. The massive sulphide deposits are related to the early rhyolitic volcanism and are concentrated in the porphyries near the upper boundary of the basal sediments (Fig. 2). Oxide, silica, and carbonate facies of iron formation as well as hematitic slates occur at a similar stratigraphic level as the sulphide deposits. The upper sedimentary sequence is characterized by lithic greywackes and dark grey to black slates. Most of these sediments are typical first cycle weathering products of volcanic rocks. Towards the margins of the district, where the volcanic rocks pinch out, there appears to be a gradational transition from lower to upper sediments. Although the Tetagouche Group as a whole was generally considered to be of Middle Ordovician age, it is now clear that the two fossil occurrences on which this age assignment is based are in the upper part of the sequence (Fig. 2). A bituminous limestone occurring between basic volcanics of Camel Back Mountain in the northwestern part of the area yielded trilobite and conodont faunules that are of Early Porterfield age (approx. zone 11 of Berry, 1962) (W. T. Dean, personal communication, 1971). Black slates of the upper sedimentary sequence near Bathurst contain graptolites which were described by Ami (1905) and Alcock (1941). An examination of this fauna by W. T. Dean of the Geological Survey of Canada (oral communication, 1971) indicated that these graptolites are clearly younger (zone 12 to 13 of Berry, 1962) than the trilobite and conodont fauna from the limestone lens at Camel Back Mountain.

Rocks of the Tetagouche Group are intruded by small stocks of gabbro and granites that were deformed and regionally metamorphosed together with their country rocks. Large bodies of granitic rocks including only minor amounts of gabbros post-date most of the deformation and regional metamorphism of the Tetagouche Group.

REGIONAL METAMORPHISM

Regional metamorphism increases from the northeast to the southwest along the axis of the Miramichi geanticline. In the northeast subgreenschist assemblages containing prehnite and pumpellyite are locally preserved within the area characterized by the occurrence of relic igneous clinopyroxene in the basic volcanic rocks (Fig. 1). The rocks north of a line connecting Brunswick Mines and Portage Lakes and in the southeastern part

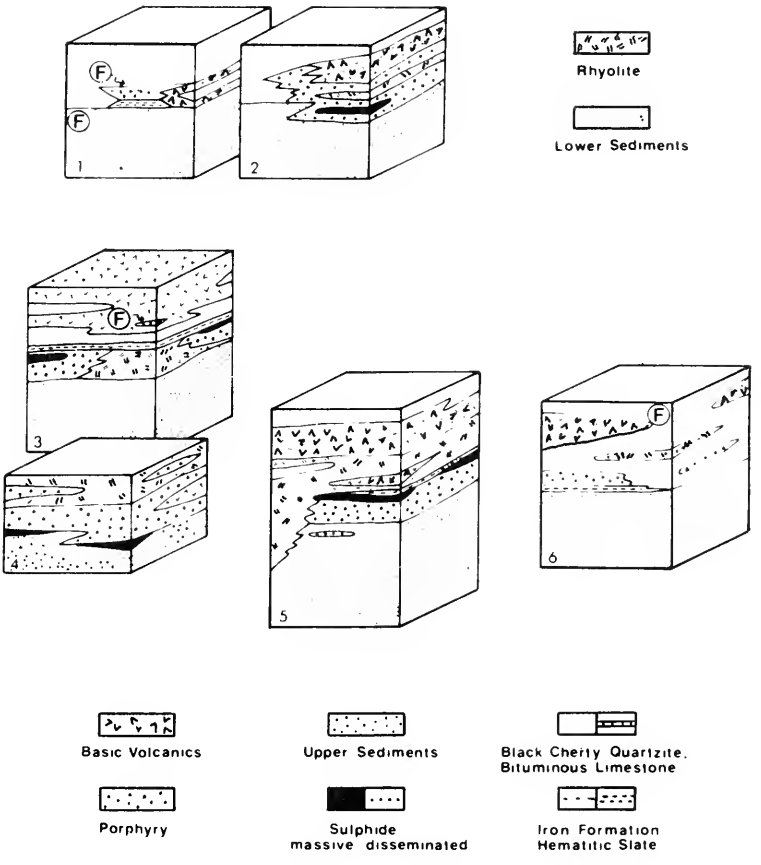


Fig. 2 Diagram illustrating stratigraphic relationships of Tetagouche Group to Ordovician rocks of Central New Brunswick.

1. Hayesville Area, Central New Brunswick (Poole, 1963).
2. Clearwater area (Area IV), (Helmstaedt, in press).
3. Portage Lakes area (Area II), Helmstaedt (1971).
4. Heath Steele area, modified after McMillan (1969).
5. Brunswick Mines area (Area III), (Helmstaedt, in press: modified after Boyle and Davies, 1964, and Stockwell and Tupper, 1966.)
6. Lower parts of Tetagouche and Middle Rivers (Helmstaedt and Skinner, in preparation).

(Fig. 1) are in the chlorite subfacies of the greenschist facies. Stilpnomelane is a common mineral in this zone. Sodic amphiboles (magnesioriebeckite and crossite) are found in laminated, magnetite-bearing basic schists which extend for about 25 miles around the nose of the Tetagouche Lakes fold (Fig. 1). The sodic amphibole-bearing assemblages are characteristic of the glaucophanitic greenschist facies of Winkler (1967) and represent the only known occurrence of such rocks in the northern Appalachians. Rocks in the southwestern part are mainly in the biotite subfacies. Garnet occurs locally in the extreme southwest (Area IV).

Evidence that the sulphide deposits have been affected by the regional metamorphism was found near the Clearwater deposits (Area IV) where pyrite in contact with biotite reacted to form pyrrhotite and phlogopite. On the regional scale pyrrhotite-bearing assemblages are restricted to sulphide deposits in biotite-bearing country rocks (Fig. 1). The only deposit with significant amounts of pyrrhotite but situated outside the biotite isograd is the Key Anacon deposit near the western boundary of Area III (Fig. 1). However, as seen from the occurrence of post-D_2 andalusite porphyroblasts in pelitic country rocks, this deposit lies within the contact aureole of the Bathurst granite. Contact metamorphic biotite occurs approximately 500 yards north of the Key Anacon deposit.

In contrast to the regionally metamorphosed rocks of the Tetagouche Group the Silurian-Devonian rocks in the north and northwest (Fig. 1) have been affected only by a burial metamorphism. Zeolite-bearing assemblages have been reported from these rocks by Helmstaedt (1971) and Mossman and Bachinski (1972).

STRUCTURAL GEOLOGY

Three regionally developed sets of structures are developed in all four areas (Figs. 1, 3). The observed fabric elements are summarized on Table I. Additional fabric elements are found locally (for instance, the local post D_1 crenulation cleavage in Area III, and D_4 structures in Area IV), but they do not appear to influence the overall geometry.

D_1 was accompanied by regional metamorphism throughout the region. The continuation of metamorphic conditions beyond D_1 is indicated by porphyroblasts of stilpnomelane (Areas I and II), stilpnomelane, muscovite, and biotite (Area III), and albite, muscovite and biotite (Area IV), that cut across the S_1 foliation. Progressive metamorphism had essentially subsided during D_2

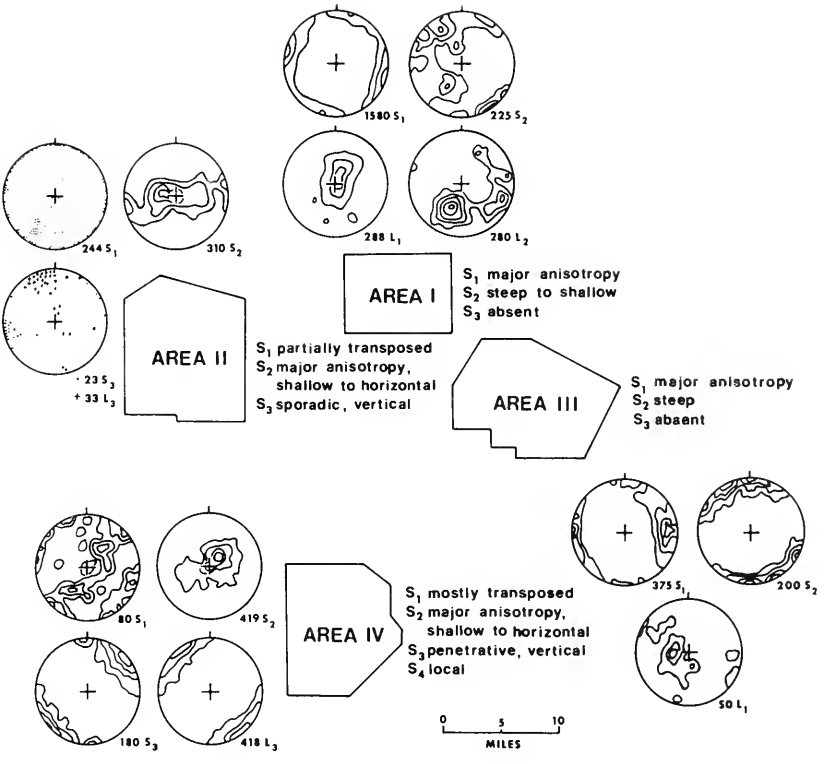


Fig. 3 Summary diagram of fabric elements in Areas I to IV (for location see Figure 1).

Contours:	Area I	S_1	1, 3, 12%
		S_2	1, 2, 4, 6%
		L_1	1, 5, 10%
		L_2	1, 2, 3, 6, 9%
	Area II	S_2	1, 2, 4, 7%
	Area III	S_1 and S_2	1, 3, 6, 12%
		L_1	1, 10, 15%
	Area IV	S_1	1, 2, 4%
		S_2	1, 3, 6, 12%
		S_3	1, 3, 6, 9%
		L_3	1, 4, 10%

in areas I, II, and III, where F_2 crenulations deformed the S_1 metamorphic fabric as well as the porphyroblasts, and little or no neocrystallization was observed along S_2. Biotite continued to be stable during D_2 in the central part of Area IV, but it was retrogressively metamorphosed to chlorite during D_3.

The style of D_1 and D_2 is essentially alike in all areas. However, there are important differences in orientation and degree of development of the crenulation cleavage S_2. Whereas S_2 is moderately to steeply dipping in most of Areas I and III, it is shallow to horizontal in Areas II and IV (Fig. 3). The change from steep to shallow dips coincides with the higher mobility in Areas II and IV during D_2 resulting in more penetrative D_2 structures.

D_3 structures in the northeast (Areas I and III) differ significantly from those in the west and southwest (Areas II and IV). Penetrative minor D_3 structures are not developed in Areas I and III, and the major F_3 closures (Figs. 1, 4) have steep axes. Minor D_3 structures are present in Area II and become more

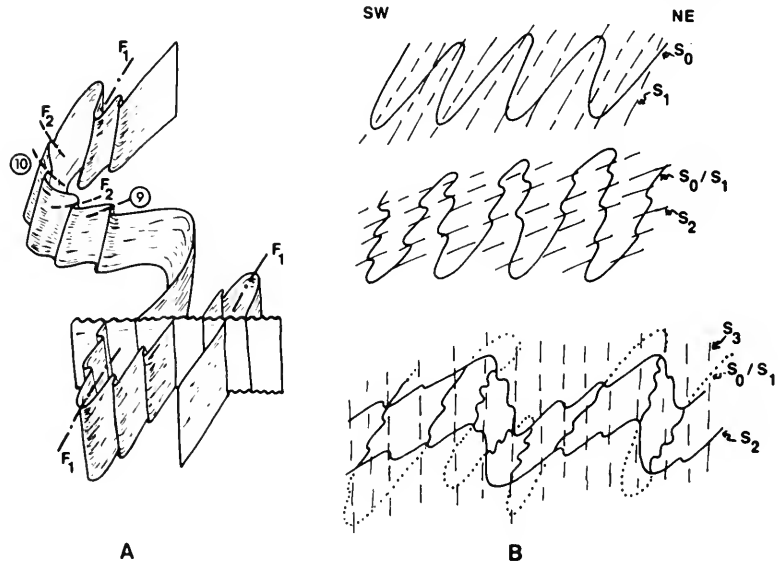


Fig. 4 Sketches illustrating difference in structural style between northeastern and southwestern parts of Bathurst-Newcastle district.

A. Diagram illustrating folding of S_0 in Area III (see Figure 1). Not to scale.
Note the consistent z-sense of asymmetry of F_2 in folds around steeply plunging F_3 closure.
Numbers correspond to field trip stops in road log.

B. Hypothetical sections showing the structural evolution in Area IV. Interference patterns as illustrated in the lower diagram have been observed on the mesoscopic scale. F_3 folds have horizontal axes and a penetrative S_3 as axial plane cleavage.

penetrative in Area IV, and the major F_3 folds in both areas have shallow to horizontal plunges. The difference in plunge of the F_3 folds is a consequence of the different planes of anisotropy utilized in the F_3 folding. In Areas I and III the steep S_1 surface was the major plane of anisotropy and its folding produced steeply plunging structures (Fig. 4A). In Areas II and IV a penetrative near-horizontal S_2 that partially transposed S_1 was developed prior to D_3. The buckling of this strong anisotropy during D_3 produced shallow plunging folds (Fig. 4B).

The overall geometry of the Bathurst-Newcastle district is still unclear. Skinner (1956) produced plasticine models by folding initially flat-lying strata about a horizontal northwesterly striking axis and refolding about a northeasterly striking axis. The pattern obtained upon slicing the model appears to resemble the map pattern. There is no doubt that the geometry in Areas I and III is the result of the refolding of isoclinal folds (F_1) during F_3 with minor modifications due to F_2. A realistic model will depend largely on the recognition of the extent of isoclinal folding during F_1 and a knowledge of the stratigraphic sequence. In models for the western and southwestern part the effect of D_2 cannot be neglected, because a penetrative S_2 determined the structural behaviour during D_3. Figure 1 is a structural compilation differentiating the lower and upper sediments of the Tetagouche Group and showing the potential usefulness of hematitic slates and iron formation as marker horizons. A more detailed discussion of the regional geometry will be forthcoming in a paper by Helmstaedt and Skinner (in preparation).

The Ordovician Folded Belt is generally regarded as a Taconic folded zone that has been refolded during the Acadian orogeny (Smith and Skinner, 1958; Neale et al., 1961; Poole, 1967; Davis, 1972). Evidence that D_1 and D_2 fabrics in Area II are pre-Upper Silurian was presented by Helmstaedt (1971). Although there is uncertainty as to the age of D_3, the lack of a geometric correlation of structures in the Silurian-Devonian with those of the Tetagouche Group in Area II (Helmstaedt, 1971; Helmstaedt and Skinner, in preparation), and the direct correlation of penetrative D_3 structures to areas that reached higher grades of regional metamorphism during the Taconian orogeny appear to be stronger arguments in favour of a late Taconian age of D_3. A K-Ar age of 424 ± 17 m.y. of muscovite from a gneiss in Area IV in which D_3 was most penetrative suggests that at least in this area the D_3 event was pre-Devonian. If D_3 was indeed part of the Taconian Orogeny, the penetrative effect of Acadian movements on the Tetagouche basement, apart from faulting, cannot have been profound.

THE POSITION OF THE MASSIVE SULPHIDE DEPOSITS WITHIN THE STRUCTURAL SEQUENCE

Structural studies strongly support a volcanogenic origin of the massive sulphide deposits in the Tetagouche Group. The major control of the orebodies is not structural, but stratigraphic; the sulphides are confined mainly to the upper contact of the lower sedimentary sequence and the porphyries immediately over-lying the sediments (Fig. 2). The location of an orebody is the consequence of the relationship between volcanic centers (Fig. 1) and the basin configuration as originally suggested by Holyk (1957), Stanton (1959), and McAllister (1960). The ore formation predates penetrative deformation and regional metamorphism (Helmstaedt, 1971) and the geometry of the ore bodies varies with the structural style of the host rocks.

ACKNOWLEDGEMENTS

The author's work in this area was conducted under the auspices of the New Brunswick Department of Natural Resources and the Geological Survey of Canada. The cooperation, guidance in the field, and information received from company geologists, members of the New Brunswick Mineral Resources Branch, the Geological Survey of Canada, and the Geology Department of the University of New Brunswick are gratefully acknowledged.

LOG AND STOPS

MILEAGE	
0	START — Bathurst, City Motel
	Highway 11 to West Bathurst
1.9	Turn south on road to Tetagouche Falls.
9.4	STOP 1 — Tetagouche Falls outcrops near Falls and on road showing crystal tuff, red manganiferous slates and upper sediments.
	Continue past Imhoff onto new road to St. Quentin (under construction)
18.7	STOP 2 — Road cut, deformed pillow lava
24.2	STOP 3 — Metavolcanic rocks on N-S limb on Tetagouche fold. Steep S_1, L_1, shallow southerly plunging L_2 occasional S_2.

24.7 Turn north on lumber road, proceed 0.6 mile to north.

STOP 4 — Just south of South Tetagouche River. "Augenschist" with feldspars and quartz elongated along near-vertical L_1. Return to St. Quentin road, proceed to west.

25.9-26.3 STOP 5 — Stilpnomelane-bearing metarhyolite on E-W limb of Tetagouche fold. L_2 shallow plunging to SE and E.

Following stop 5 there are two options to be decided depending on road conditions, weather, and preference of participants on field trip.

Option I Continue westwards past Caribou Mines into 18 Mile Brook area on lumber roads, approximately 15 miles.

STOP 6 — SE Depot on Upsalquitch River containing pebbles of Tetagouche Group. Upper Silurian conglomerate.

STOP 7 — 19 Mile Brook. Unconformity of Upper Silurian conglomerate on Tetagouche Group basic metavolcanics.

STOP 8 — Upsalquitch Lake. Southwest of old Lumber Camp near north end of Lake. Structures in lower sedimentary unit.

Additional stops if time permits. Return via Dalhousie.

Option II Return from stop 5 to Bathurst and take Bathurst Mines Road.

0 Bank of Montreal, center of Bathurst.

16.9 Junction to Brunswick No. 12 Mine.

Continue towards Brunswick No. 12.

19.9 STOP 9 — Papineau River
"Augenschist" on E-W limb of F_3-fold
NE striking S_2 (See fig. 4A).

21.1 STOP 10 — Just before Brunswick No. 12 Mine turn SW across Hauling Road. Walk towards Papineau River, N-S limb of F_3-fold, SE striking S_2 (See Fig. 4A).

24.3 Return to junction to Brunswick No. 6, go south towards Brunswick No. 6.

25.4 Turn left (east) towards Grand Falls.

26.3 STOP 11 – Road bends to south.

Outcrop of Lower sediments.

27.9 STOP 12 – Nepisiguit Falls. Quartz-feldspar augen-schist ("porphyry").

Contact to Lower sediments below falls.

Continue east along Nepisiguit River.

STOP 13 – Austin Brook Iron Mine. Minor structures in oxide and sulphide facies of iron formation and their country rocks.

Return to Bathurst.

TRIP A-6, by A. L. McAllister, The University of New Brunswick.

THE BATHURST MINING CAMP

The N.E.I.G.C. field trip to the Bathurst-Newcastle area will provide those interested in mining geology an opportunity to study massive stratiform sulphide deposits and the general aspects of the geological environment in which they occur. Limitations of time confine the excursion to the immediate area of three of the largest of the known deposits: Brunswick No. 12, Brunswick No. 6 and Anaconda Caribou.

REGIONAL GEOLOGY

The massive sulphide bodies occur in a highly deformed volcanic pile which underlies over 700 square miles of northern New Brunswick. The general geology is indicated in Fig. 1 which also shows the location of significant deposits. The pile includes sedimentary rocks, gabbroic and dioritic intrusions, at least one ultramafic plug, and later Devonian granite stocks and batholiths.

The volcanic (units 0_2, 0_3, and 0_4 in Fig. 1) and the enclosing meta-sedimentary rocks have been generally included in the Tetagouche Group and assigned a middle Ordovician age on the basis of one or two fossil localities, both of which occur near the periphery of the outcrop area. Recent structural studies have suggested that the bulk of the volcanic rocks and associated sedimentary rocks, including the indicated deposits (except Nigadoo) may be older.

The stratigraphy of the pre-Silurian rocks is summarized below:

Ordovician (in part Middle Ordovician)	Tetagouche Group	tuff, flows, quartz-sericite schist, biotite-chlorite schist; minor slate and mafic metavolcanic rocks.
		Augen schist: quartz and quartz-feldspar augen schist, quartz-sericite schist, quartz-chlorite (biotite) schist; minor mafic metavolcanic rocks, and metasedimentary rocks.
		Metasedimentary rocks: (a) phyllitic slate, argillite, greywacke, siliceous argillite;

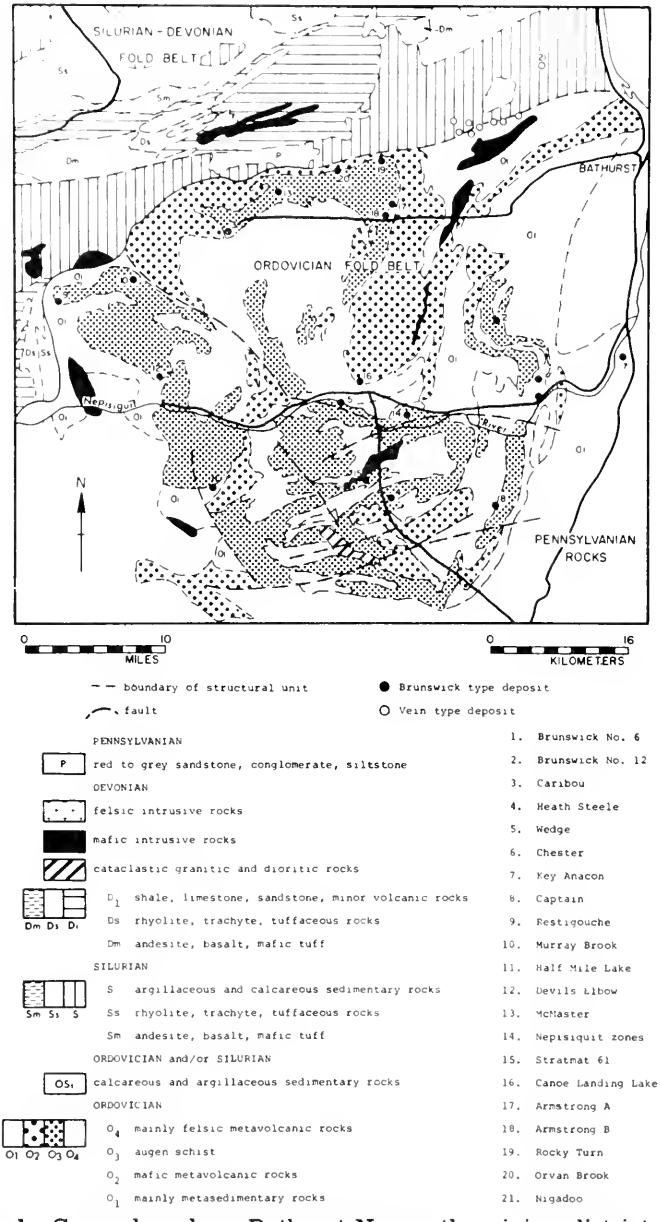


Fig. 1 General geology Bathurst-Newcastle mining district (J. L. Davies).

(b) feldspathic sandstone, quartz-chlorite and quartz-sericite schist, minor slate.

Mafic metavolcanic rocks:
(a) spilite, greenstone, minor trachyte and metasedimentary rocks;

(b) greenstone, mafic metatuffaceous rocks, red and grey slate and phyllite.

Intense structural deformation coupled with low grade metamorphism is a characteristic feature of the rocks older than Silurian. Steep isoclinal folding has been produced during one and possibly two periods of orogeny, and deformation of lesser intensity has been superimposed upon them.

Studies of minor structures, carried out in widely separated parts of the camp, have indicated at least three periods of deformation and as many as six (Helmstaedt 1970, Fyffe 1970, McBride 1973, Luff 1973). The relationship of the individual deformational periods to the Taconic and Acadian orogenies is not clear, but the earlier periods produced the isoclinal folds and a strong schistosity. Later phases resulted in broad open folds with prominent fracture or crenulation cleavage and kink bands.

Stong transcurrent faults striking N70-80°E having right-hand displacements of up to fourteen miles have been mapped. A second set of faults strikes between north and northwest.

SULPHIDE DEPOSITS

The three deposits, Anaconda Caribou, Brunswick No. 12 and Brunswick No. 6 are typical of the many sulphide deposits of the volcanic pile. They are generally concordant, fine grained, pyrite-sphalerite-galena - chalcopyrite - pyrrhotite bodies, occurring in sedimentary rocks at or near their contact with a quartz-feldspar - augen schist which is generally interpreted as ash-flow tuff.

Two types of mineral assemblage are found:

1) Massive pyrite, commonly imperfectly banded, containing sphalerite, galena and minor chalcopyrite and pyrrhotite with small amounts of arsenopyrite and tetrahedrite-tennantite.

2) Pyrrhotite-chalcopyrite assemblages as lenticular zones containing veins and pods of massive sulphides.

The sedimentary rocks near ore bodies are most commonly iron-rich chlorite schists, iron formation and chlorite-sericite-(biotite) schist but sericite schists, chert and dark argillites are also found. Barite and siderite are found in places.

Brunswick No. 12 Mine: (After D. Rutledge, 1972) The general geology of the Brunswick No. 12 Mine is indicated in Fig. 2, and in the table of formations as follows:

Table of Bedrock Formations
Near Brunswick No. 6 and No. 12 Mines

Period or Epoch	Group	Lithology
Ordovician (?)		Quartz-feldspar porphyry dyke Metadiabase and metagabbro
	Intrusive Contact	
Ordovician (?)	Tetagouche	a) Upper volcanic rocks b) Iron formation (including sulphides) c) Augen schist d) Metasedimentary rocks.

The beds lie in tight isoclinal folds with axial planes striking northwest and dipping steeply west. A later stage of folding has axes plunging steeply to the west. The folds are cut by faults which strike northwest roughly parallel to the ore body and schistosity of the enclosing rocks.

The No. 12 Main Zone is a roughly lenticular mass which fingers out at the ends. The deposit strikes north-south, dips about 75 degrees west and plunges almost vertically. At surface the sulphide body is 1300 feet (395 m) long and 100 to 200 feet (30-60 m) wide. About two-thirds of the sulphide mass in the upper part of the mine is lead-zinc ore, the remainder being essentially massive pyrite. With increasing depth, the size of the pyrite body becomes greater without reduction of volume of lead-zinc ore.

The West Zone dips steeply westward but steepens to almost vertical at a depth of about 1900 (575 m) feet, and thus gradually converges with the Main Zone. The West Zone apex is about 350 feet (105 m) below surface and it continues to a depth of 3400 feet (1030 m) with no apparent diminution in size and grade.

The sulphide deposits consist of 80 to 90 per cent of predominantly fine-grained sulphides, mainly pyrite, sphalerite, galena, chalcopyrite, tetrahedrite and bornite. Small amounts

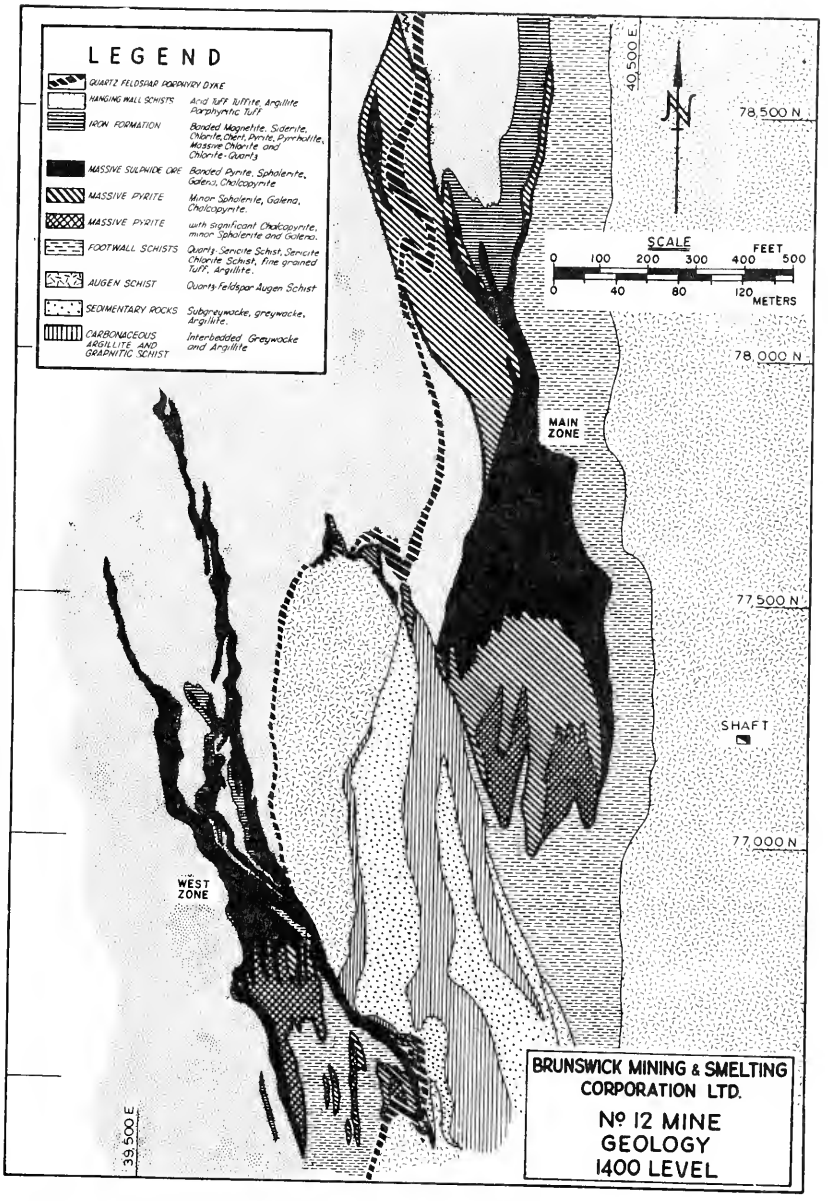


Fig. 2 Geological plan, 1400 ft. level, Brunswick No. 12 Mine.

of stannite, cassiterite, boulangerite, domeykite and unnamed silver sulpho-salts have been reported. While the mode of occurrence of silver is not well known, its distribution largely corresponds with that of lead-zinc. A slight correlation of silver and copper has been observed which presumably is related to silver-rich tetrahedrite. Magnetite is relatively uncommon in the massive sulphides, but is considerably more abundant in more or less isolated lenses of iron formation. Quartz is the most abundant non-metallic mineral. Chlorite, sericite, carbonate, graphite and other gangue minerals are common in the massive sulphides in small amounts.

In the lead-zinc ore, sulphide banding is usually parallel to the footwall or hanging wall contacts, but folding has produced many local exceptions.

The zoning in the No. 12 Main Zone is somewhat simpler than that of the structurally more complex No. 12 West Zone and No. 6 orebody and therefore a description of the first will serve best to illustrate the general pattern.

The Main Zone on the 1900 foot (575 m) level has been essentially undisturbed by folding, and the sulphide mass is a stratiform lens with banding of sulphides parallel to bedding of footwall and hanging-wall rocks. The longitudinal zoning consists of a simple, fine-grained non-foliated, pyrite mass at the south end of the sulphide body, grading quite abruptly northward into a layered, pyrite-sphalerite-galena orebody.

Transverse zoning has resulted in highest tenor Pb, Zn and Ag in the footwall third of the sulphide deposit, with the central one-third to one-half somewhat lower in grade. Toward the hanging-wall one-quarter to one-third of the mass is of sub-ore, essentially copper-poor, commonly colloform, pyrite which contains small layers and lenses of fine-grained silica and siliceous argillite.

The sulphide deposit shows a very simple and striking transverse copper zoning. Highest Cu values (greater than 0.2% copper) are confined to the footwall third of the sulphide mass, the remaining part of the mass is copper-poor. Within this footwall zone, chalcopyrite, occurs in both the pyrite rich south end and the lead-zinc rich northern portion of the deposit. The limits of the copper zoning are parallel to sub-parallel to the lead-zinc zoning and layering.

Brunswick No. 6 Mine: The stratigraphic sequence at Brunswick No. 6 Mine is generally similar to that at Brunswick No. 12, in that a thick layer of ash flow material, now deformed to augen

schist, is overlain by a zone of chemically precipitated sedimentary rocks including sulphides, chlorite schist, chert and oxide – carbonate iron formation, which is in turn overlain by a primarily volcanic sequence (see Figure 3).

The beds in the ore zone form tight isoclinal folds plunging steeply south in the north half of the pit and steeply north in the south half of the pit.

The ore zone contains massive fine-grained pyrite at the base overlain by layered pyrite galena-sphalerite with variable amounts of chalcopyrite, and a hanging wall pyrite zone containing minor sphalerite and galena and little copper.

A tabular heel of pyrrhotite-chalcopyrite extends down plunge from the thick footwall pyrite into the footwall rocks.

The mineralogy is generally similar to the No. 12 deposit.

Caribou Mines: (After R. Cavalero, 1970) At the Caribou mine massive stratiform sulphides occur around a broad open well-deformed steeply north plunging synform over a strike length in excess of 4000 feet (See Figure 4).

The Caribou deposit occurs within the metasedimentary rocks along their northern contact with a potassic volcanic sequence. The deposit consists of three tabular, steeply-dipping, stratiform massive sulfide lenses arranged en échélon around the nose of the Caribou synformal fold, so that the metasedimentary rocks form the footwall of the orebody and the volcanic schist the hanging wall. Two of the sulfide lenses occur along the west limb of the fold (north and south sulfide bodies) and the third along the east limb (east sulfide body).

Enclosing Rocks: The footwall metasedimentary rocks consist of two dominant types. Immediately adjacent to the massive sulfide bodies is argillaceous phyllite, normally quartz-banded, and pyritic toward the sulfide zone and containing local lenticular bodies of chlorite-pyrite-(chalcopyrite) schist. Enveloping this unit and delineating the Caribou fold structure is a relatively homogenous zone of fine graphitic phyllite and schist which has been traced well beyond the limbs of the fold.

In the nose of the fold gray pelitic phyllite separates the graphitic zone from the andesitic rock sequence to the south and west. On the limbs this unit is absent as the graphitic rocks are in contact with the meta-andesites and locally interbedded with andesitic metasiltstone toward the anticlinal hinge. A thin band of altered gabbro occurs within the graphitic zone and appears

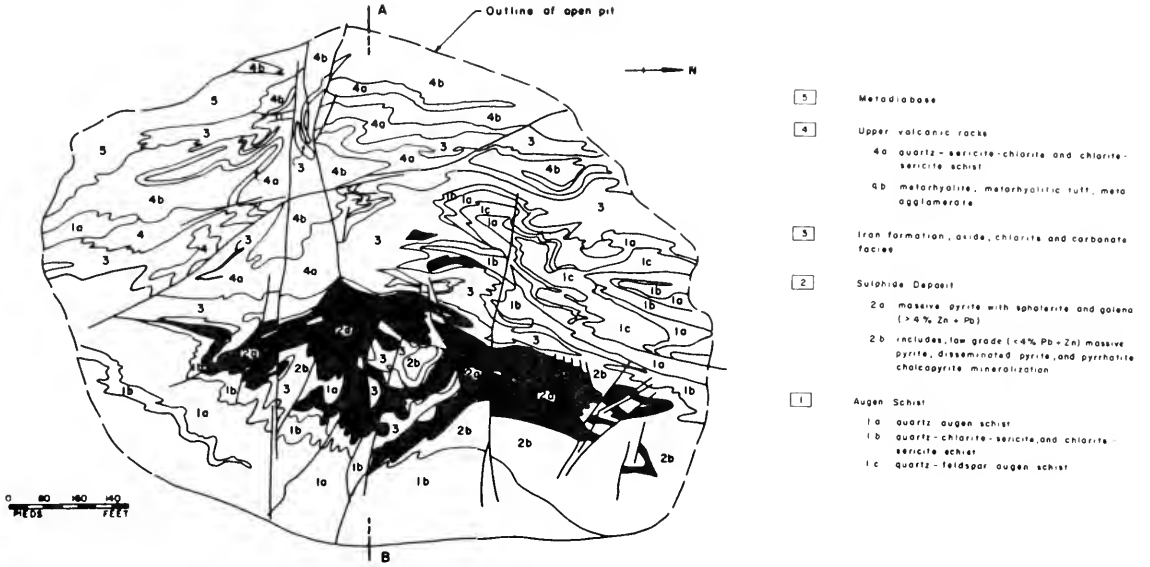


Fig. 3 Surface plan, Brunswick No. 6 Orebody, (Z. Pertold, unpub.).

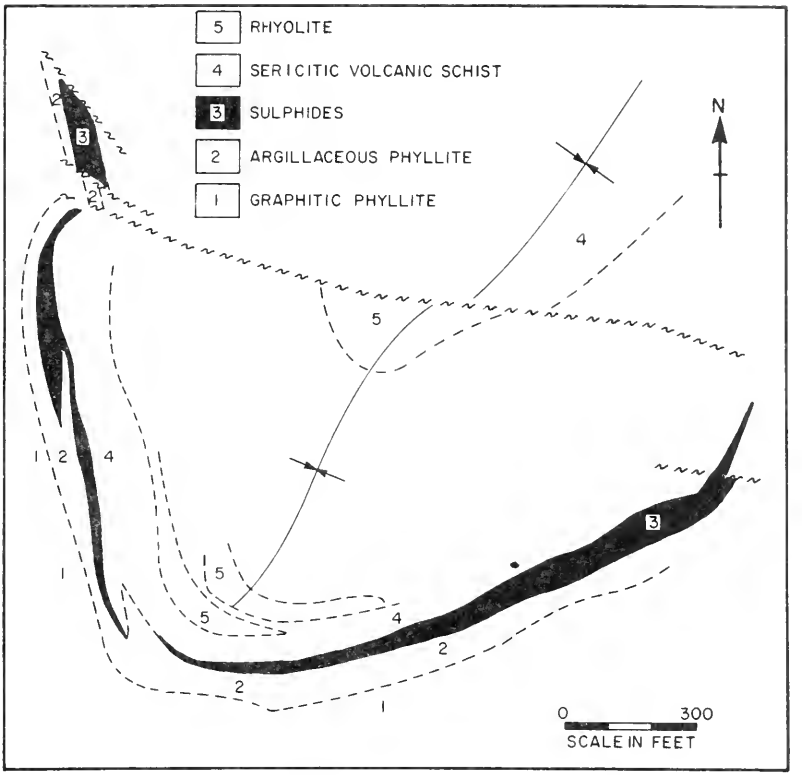


Fig. 4 Plunging synform, Caribou Mines.

to be a pre-fold sill-like intrusion. Outcrops of inclusion-bearing aplitic granite also occur between the gabbro and meta-andesite on the east limb.

Along the south half of the north sulfide body occurs a lenticular, heavily pyritic chloritic unit. It pinches out adjacent to the sulfide mass to the north and into the footwall phyllite to the south attaining a maximum width of 25 feet.

Adjacent to the south sulfide body and extending approximately 200 feet along its center is a disc-shaped lens of chloritic rock rich in chalcopyrite. The lens rarely exceeds 10 feet in width and has a down-dip length of nearly 400 feet.

Three dominant rock types occur on the hanging wall. Adjacent to the massive sulfide on the west limb of the fold is a

thin band of sericite phyllite. Toward the center of the fold is a variable sequence of volcanic schist which is in direct contact with the sulfide zone along the east limb. The core of the fold consists of potash rhyolite porphyry intercalated with schist similar to parts of that occurring nearer the ore zone.

The sulfide lenses are arranged en echelon around the Caribou fold structure. Two, the north and south sulfide bodies, occur on the west limb and are generally similar. The third, east sulfide body, occurs on the east limb and differs in some respects with the other two. Across-layer and lateral base metal zoning is a prevalent feature of the sulfide bodies and consists of high-grade Zn - Pb, low-grade pyritic, and Cu-rich pyritic zones.

The sulfide is extremely fine-grained consisting primarily of pyrite, magnetite, sphalerite, galena, and chalcopyrite. Of these, pyrite is by far the predominant with the others confined primarily to distinct zones. Minor amounts of arsenopyrite, marcasite, pyrrhotite, bornite, tennantite, and hematite are found. Chalcocite and covellite are common secondary minerals. The ore metals are zinc, lead, copper, silver, and gold in that order of abundance. The silver is normally associated with the Zn - Pb minerals, whereas the gold is much more erratic in distribution.

A finely-laminated to crudely banded texture which parallels the bounding surfaces of the sulfide and wallrock schistosity occurs throughout the sulfide bodes. The laminae are best developed in the high-grade Zn - Pb zones and result from thin, sphalerite-rich bands commonly sinuous and irregular, but fairly continuous. Within the bands sphalerite forms the matrix as irregular grain clusters. A crude banding is also exhibited in the low-grade and cupriferous pyritic zones resulting primarily from grain size variations in adjacent bands.

A third form of banding results from magnetite which occurs locally in distinct zones of irregular distribution commonly overlapping the base metal zones. The mineral, in concentrations up to 30 per cent is very fine-grained and occurs as long, sinuous laminae, irregular bands and lenses, and vermicular patches. Magnetite is abundant in the south sulfide body and north half of the north sulfide body, but occurs very locally in the east sulfide body. It has not been recognized in the wallrocks or waste bands within the massive sulfide.

Chlorite is the predominant gangue mineral in the north and south sulfide bodies. Less common are fairly continuous bands

and lenses of chlorite-(quartz)-(pyrite) schist and phyllite in which the schistosity often occurs at low angles to the sulfide contacts.

In the east sulfide body quartz is the predominant gangue mineral and locally forms the matrix for the sulfides.

Across-layer and lateral zoning are prominent features of the sulfide bodies. The across-layer zoning is characterized by concentration of Zn - Pb along the hanging wall and Cu concentration along the footwall. A low grade pyritic core separates the two zones. Lateral zoning parallel to the plane of mineralogical layering and perpendicular to the across-layer zoning takes the form of transition to massive, pyritic sulfide toward the ends of the ore bodies.

Since the top of the stratigraphic sequence has not been determined, the significance of the zonal pattern is not yet understood, but Cu-rich zones generally have been considered to lie at the base of the sulfide mass. However, in most of the other zoned deposits in the district this "base" also occurs on the footwall of the orebody, but in contact with rocks similar to those of the Caribou hanging wall.

ITINERARY

Thursday

1) Arrive in Bathurst (Thursday night Gloucester Hotel)

Friday

2) 7:00 a.m. — breakfast
3) 8:00 a.m. — leave for Brunswick No. 12
4) 8:30 a.m. — briefing at No. 12
5) 9:30 a.m. — underground
6) 12:30 p.m. — lunch
7) 1:30 p.m. — Brunswick No. 6, Austin Brook, Nepisiguit Falls
8) 6:00 p.m. — return to Bathurst
9) 7:00 p.m. — dinner

Saturday

10) 7:00 a.m. — breakfast
11) 8:00 a.m. — leave for Brunswick No. 12
12) 8:30 a.m. — tour of mill
13) 11:00 a.m. — leave for Heath Steele
14) 12:00 p.m. — lunch
15) 12:45 p.m. — surface tour — structure, stratigraphy
16) 3:00 p.m. — leave for Fredericton
17) 6:00 p.m. — arrive in Fredericton

TRIP A-7, by H. Greiner, The University of New Brunswick.

POINTE VERTE TO TIDE HEAD, CHALEUR BAY AREA, NEW BRUNSWICK

INTRODUCTION

Silurian and Devonian sedimentary, extrusive and intrusive rocks of northern New Brunswick occupy the southwest-trending Chaleurs Bay Synclinorium (Poole, W. H., and John Rodgers, 1972). These sediments and volcanics were deposited adjacent to an island arc system with a core of Ordovician and older rocks which had been deformed by the Taconic Orogeny (Bird, J. M. and Dewey, J. F., 1970). This ancient land mass, named "Miramichia" by Rodgers (1971, p. 1159), was the source of sediment and the site of volcanoes in the Lower, Middle and Upper Silurian and into the Lower and Middle Devonian. Deep-water turbidite accumulations, probably beginning in the Middle Ordovician (with argillaceous limestone or "ribbon rock" of the Matapedia Group), and continuing through the Silurian, prevailed to the west in the Campbellton-Matapedia area.

For much of the area there is a remarkable repetition, almost cyclical in character, in the Middle to Upper Silurian and in the Lower Devonian. In both an initial, marine, calcareous siltstone or silty limestone is succeeded by basalt flows, followed by terrestrial redbeds or (for the Devonian) very near-shore sedimentation, and ending with orange felsitic extrusions. (Fig. 1.)

Middle Devonian sedimentary rocks of the Campbellton Formation are lacustrine, intermontane conglomerates, sandstones and shales, with a rich fish and plant biota, and a close association with tuffs and agglomerates.

The youngest consolidated rocks are redbed conglomerates of Pennsylvanian age, the Bonaventure Formation, which lie with conspicuous angular unconformity on older rocks. They are almost flat-lying, and only rarely faulted.

Deformation was in shallow-depth zones and mainly Acadian, although local granitic to gabbroic intrusions occurred as well. Folds are open, and two fault systems dominate, one north-trending, the other to the east or northeast. Metamorphism is subgreenschist (zeolites in Devonian palagonite tuffs are not uncommon), and contact metamorphism minimal. Axial-plane cleavage is present in many of the Silurian and Devonian pelites. Appala-

chian deformation was apparently limited to gentle warping; shallow-zone faulting took place in the Dalhousie area, as well.

The Ordovician-Silurian contact is probably an angular unconformity (Fig. 2 and 3). Otherwise all formational contacts of Silurian units in the Petit Rocher-Charlo areas (but probably not in the West Campbellton) are conformable or disconformable. Indeed, the Silurian-Devonian boundary itself appears to be one of conformity, and lies somewhere within a calcareous siltstone-mudstone sequence. As might be expected, facies chnge can be great (Fig. 4).

Contacts between the various Devonian sedimentary formations are in general more complex, with much injection and extrusion of igneous rocks, and interfingering and "pinching-out" of units. The Archibald Settlement Felsites in the Charlo area are conspicuously unconformable, as, indeed, is the Bonaventure Conglomerate.

LOG AND STOPS

MILEAGE

FRIDAY, OCTOBER 12, 1973

0.0. T-intersection at King Avenue and Main Street, Bathurst. Turn left onto Route 11.

2.4 Tetagouche River. Middle Ordovician graptolite locale ca. one mile upstream in graphitic slate and chert of the Tetagouche Group.

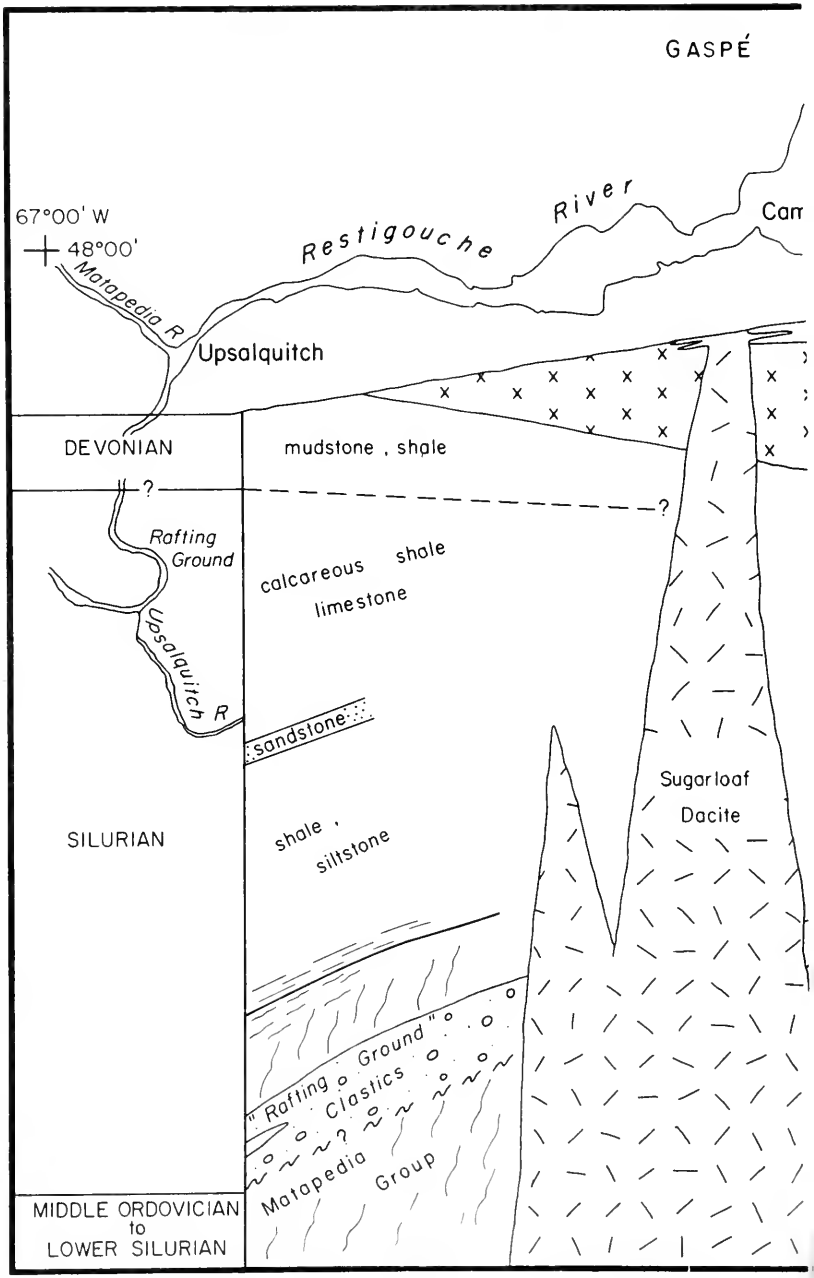
3.5 ¼ mile west to graptolite site.

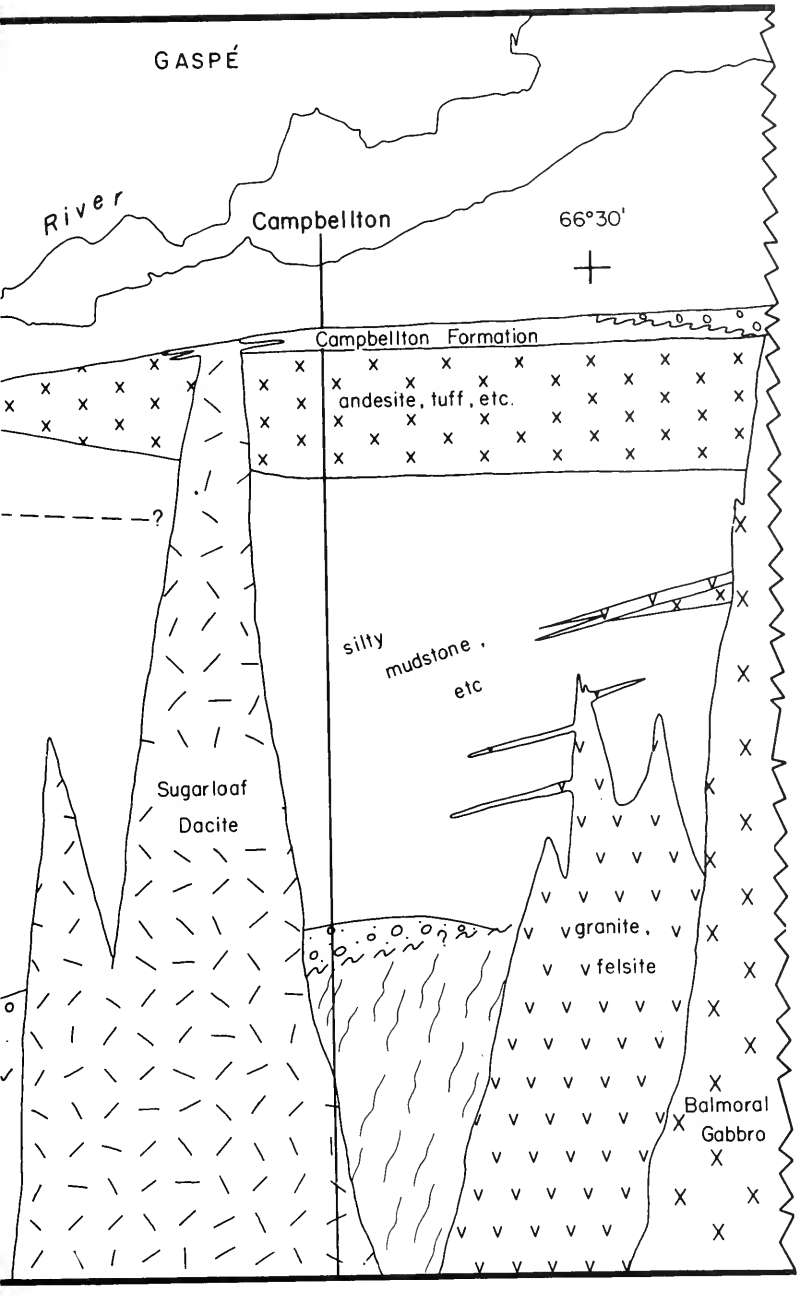
3.8 Pillow basalt flows, probably Devonian.

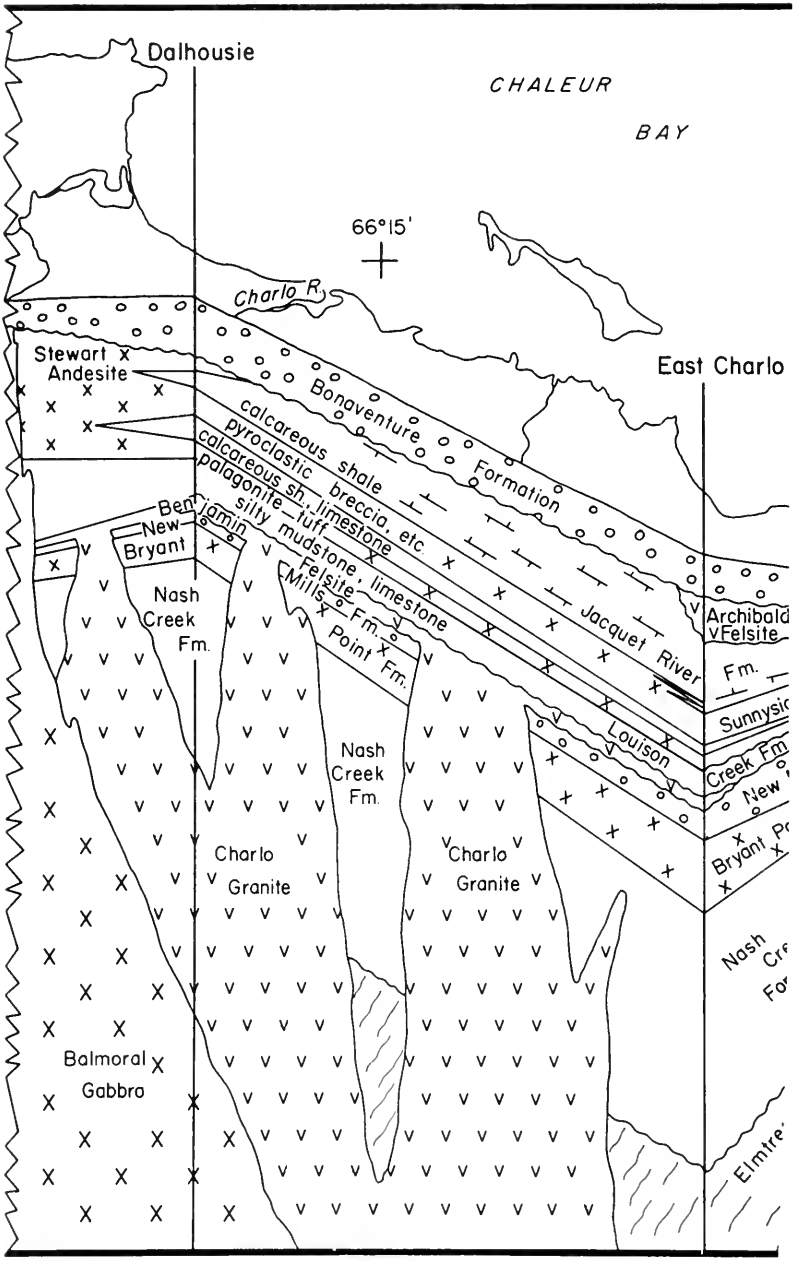
6.1 Grants Brook. Ordovician Tetagouche metasedimentaries. Just beyond, cross Rocky Brook-Millstream Fault zone into Silurian siltstone, shale-limestone rocks. Gaspe visible across Chaleur Bay.

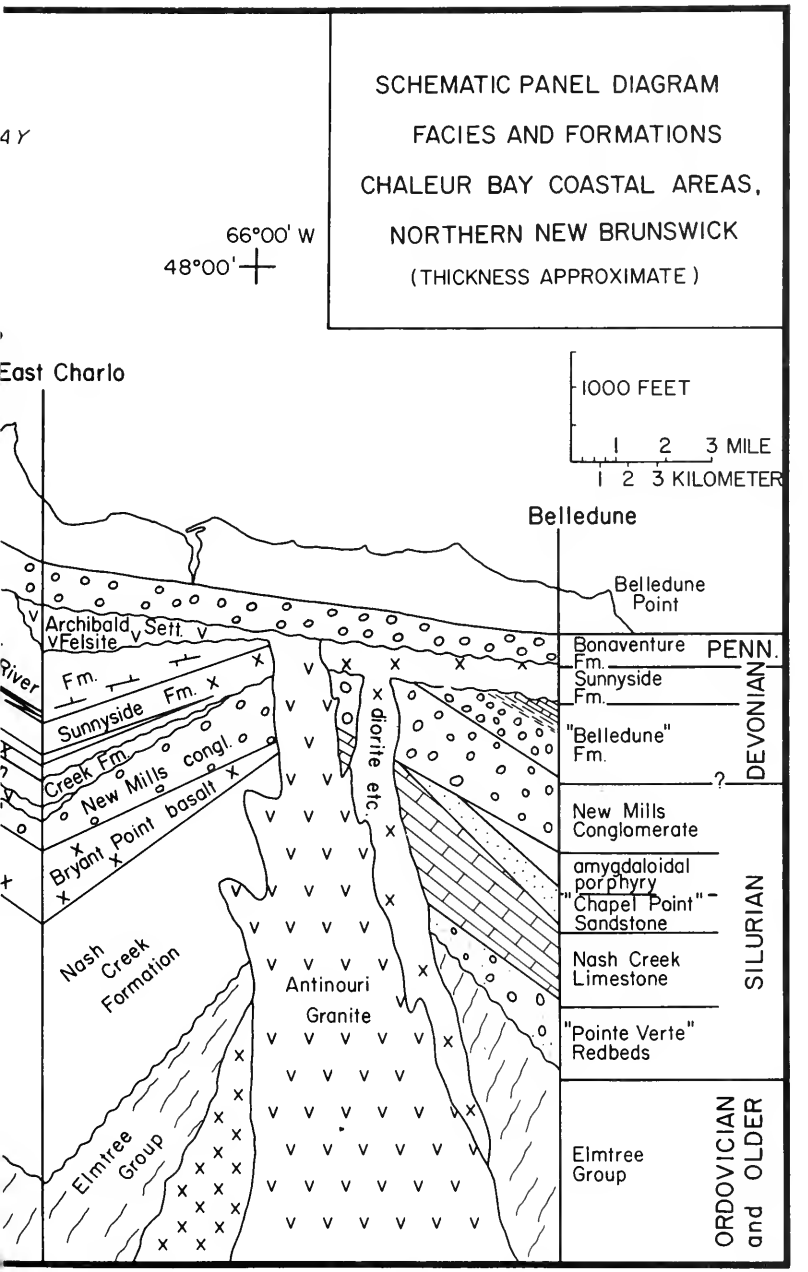
9.7 Nigadoo River. Silurian.

14.4 STOP 1 — Limestone Point. Silurian sedimentary rocks lie with probable unconformity on Elmtree (-Tetagouche) phyllite, quartzite, etc., and are unconformably overlain by Devonian andesitic flows. The Silurian section here begins with Lower (but probably not lowest) Silurian redbed rudites, tentatively named the "Pointe


GASPÉ
67°00' W
48°00'
Restigouche River
Matapedia R
Upsalquitch
DEVONIAN
mudstone , shale
?
?
Rafting Ground
Upsalquitch R
calcareous shale
limestone
sandstone
SILURIAN
shale , siltstone
Sugarloaf Dacite
"Rafting Ground" Clastics
Matapedia Group
MIDDLE ORDOVICIAN to LOWER SILURIAN


GASPÉ
River
Campbellton
66°30'
Campbellton Formation
andesite, tuff, etc.
?
silty
mudstone,
etc
Sugarloaf
Dacite
granite,
felsite
Balmoral
Gabbro


Dalhousie
CHALEUR
BAY
66°15'
Charlo R.
East Charlo
Stewart
Andesite
Bonaventure Formation
calcareous shale
pyroclastic breccia, etc
calcareous sh., limestone
palagonite tuff
silty mudstone, limestone
Felsite
Mills Fm.
Point Fm.
Jacquet River
Archibald
Felsite
Fm.
Sunnysi
Louison
Creek Fm
New
Bryant Pc
Benjamin
New
Bryant
Nash
Creek
Fm.
Nash
Creek
Fm.
Charlo
Granite
Charlo
Granite
Balmoral
Gabbro
Nash
Cre
Fo
Elmtre


SCHEMATIC PANEL DIAGRAM
FACIES AND FORMATIONS
CHALEUR BAY COASTAL AREAS,
NORTHERN NEW BRUNSWICK
(THICKNESS APPROXIMATE)
66°00' W
48°00'
1000 FEET
1 2 3 MILE
1 2 3 KILOMETER
East Charlo
Belledune
Belledune Point
Archibald Sett
Felsite
Fm.
Sunnyside Fm.
Creek Fm.
New Mills congl.
Bryant Point basalt
Nash Creek Formation
Elmtree Group
diorite etc.
Antinouri Granite
Bonaventure Fm.
Sunnyside Fm.
"Belledune" Fm.
New Mills Conglomerate
amygdaloidal porphyry
"Chapel Point" Sandstone
Nash Creek Limestone
"Pointe Verte" Redbeds
Elmtree Group
PENN.
DEVONIAN
SILURIAN
ORDOVICIAN and OLDER

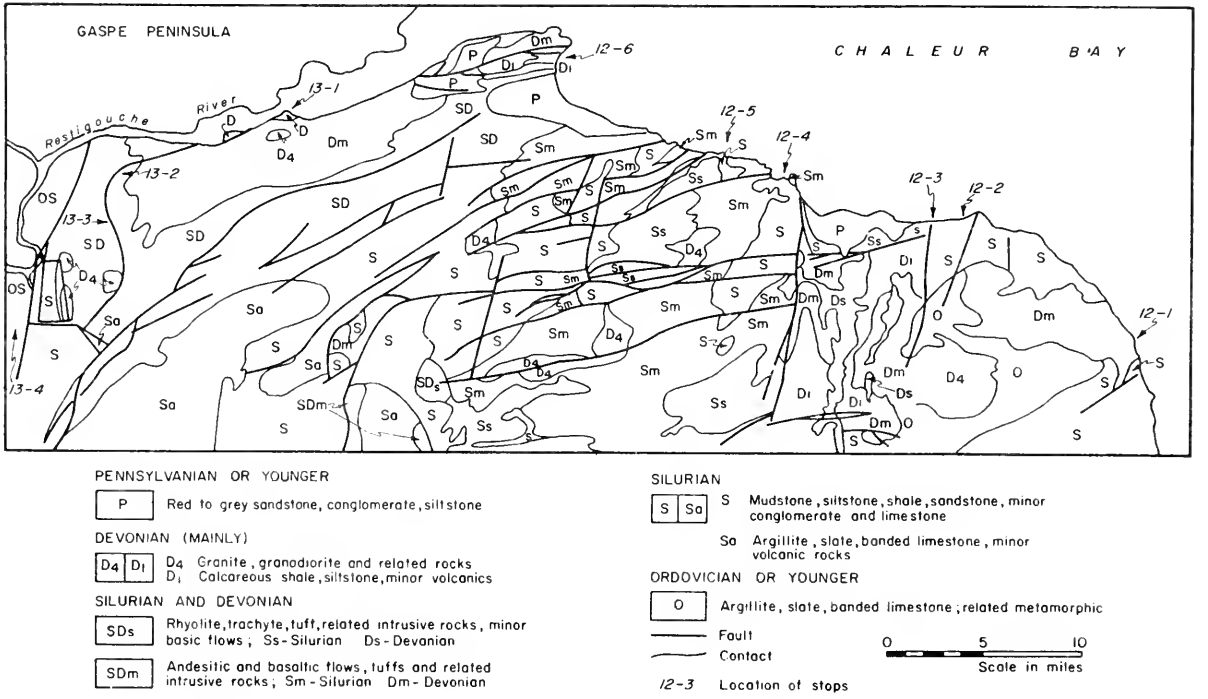


Fig. 2 General geology, Chaleur Area, New Brunswick.

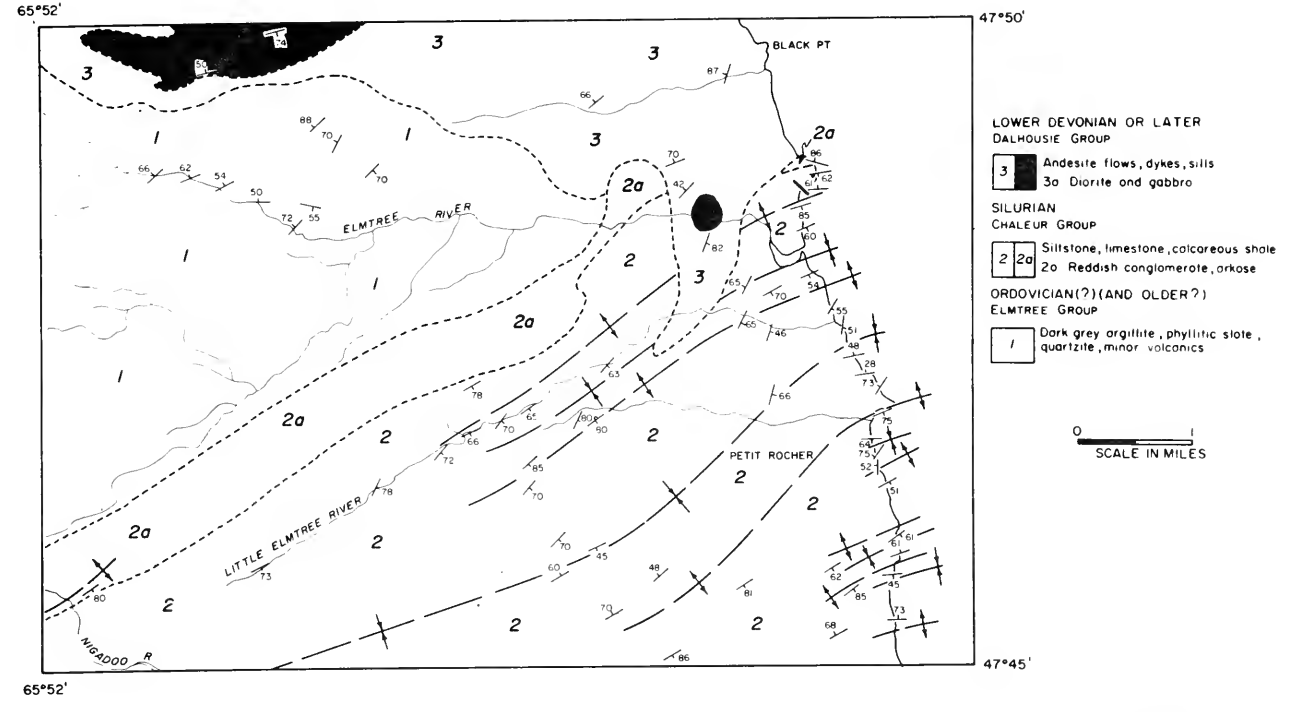


Fig. 3 Ordovician-Silurian-Devonian contact relations, Limestone Point, New Brunswick.

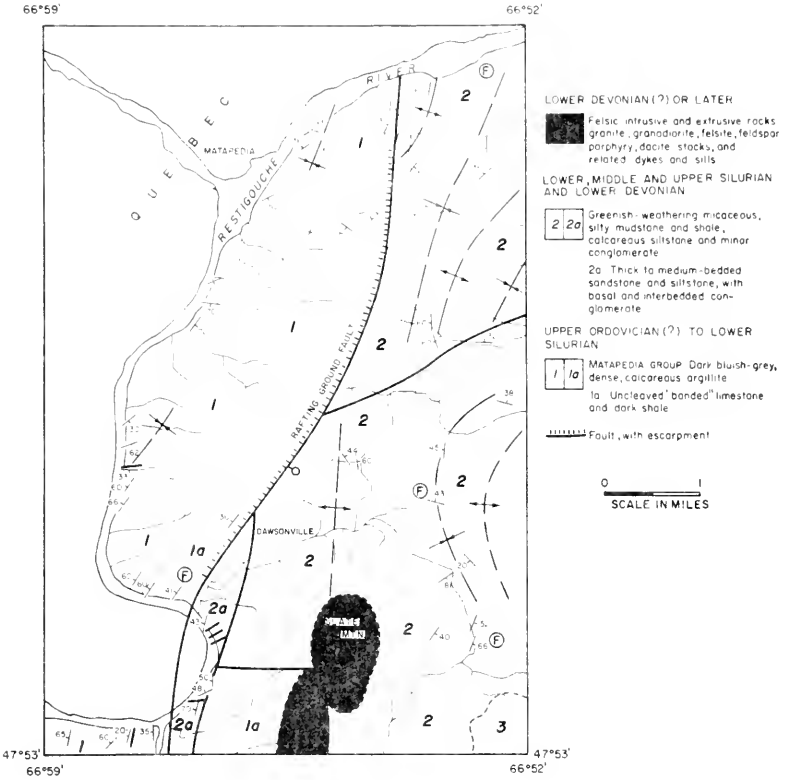


Fig. 4 Ordovician-Silurian-Devonian contact relations, Restigouche River estuary, New Brunswick.

Verte Redbeds," with minor andesitic flows, and is succeeded by typical, widespread, nodular "pitrock" limestone, roughly equivalent to the Gaspe La Vieille Formation of upper Llandovery-Wenlock age. This is the Nash Creek Limestone.

Especially interesting here are the intense slump folds penecontemporaneous with deposition of the sediment. Time permitting, a side trip up the Madran road to the railroad crossing to see a small gabbroic neck — the probable source for the andesite flows — and, farther on, to view the Elmtree metasedimentaries will be made.

15.5 Dark greenish-grey basalts, etc., begin.

17.5 Green Point crossroad. Silurian, as before.

22.4 Smelter. Lead and zinc.

23.3 Church at Turgeon.

23.6 STOP 2 – At Turgeon the conspicuously jointed "Chapel Point" reddish sandstones (which, nearby, can be seen resting on the Nash Creek Limestone) is succeeded by mafic, amygdaloidal porphyry which contains large phenocrysts of feldspar. Boulders of this porphyry, as well as of many other igneous rocks, and of the Nash Creek Limestone, can be found in the succeeding New Mills Conglomerate, a typical fanglomerate. Plucked "rip-up" limestone clasts are common, sorting is poor. Such structureless, unsorted conglomerates have been said to indicate surge deposition within a fanglomerate.

27.8 Belledune River; Lower Devonian fossiliferous siltstone in river.

28.3 Cross fault into probable basal Silurian (Llandovery) redbeds.

30.7 Turn right onto dirt road (just before bend, Rte. 11), and proceed to shore at Flanagan's house.

STOP 3 – Fault zone at creek: to west, Nash Creek siltstone, Bryant Point basalt, New Mills Conglomerate, with associated mafic intrusions; to east (right), "Pointe Verte Redbeds" in a finer, partially marine, crossbedded facies, grading into (overturned) fossiliferous Nash Creek Limestone at Quinn Point. All steeply dipping, with the Bonaventure Formation in angular unconformity above.

Paleobathymetric analysis of the Nash Creek shows three of the five depth-zone indicators of Ziegler (1965) are present; the shallowest (Lingula, of the Welsh strata) is replaced by algal heads, here. Carboniferous tropical weathering (Rodgers, John, pers. comm.) is prevalent.

33.6 Jacquet River Provincial Park. Bonaventure redbeds.

34.7 Jacquet River Bridge; Bonaventure on east Bank.

38.1 Again Silurian.

40.0 Road to Dickie Cove.

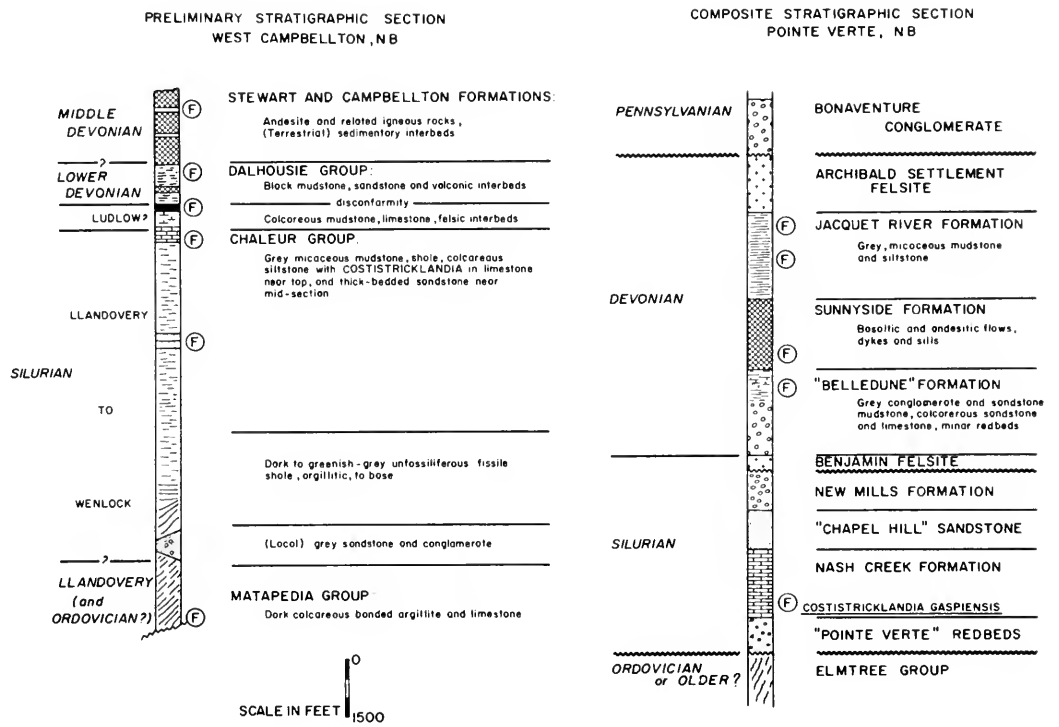


Fig. 5 Comparative columnar sections for areas illustrated by Figures 3 and 4.

STOP 4 – Nash Creek Formation in a ripple-marked, worm-burrowed calcareous siltstone facies. Note the kame ridge.

43.6 New Mills and Federal Salmon Pond.

STOP 5 – Bryant Point-New Mills contact. Bus proceeds to Cove at Thrum Island. Heron Island with flat-lying Bonaventure offshore. Archibald Settlement (Devonian) rhyolite forms hills inland.

48.9 River Charlo. Bonaventure forms bedrock.

50.2 Approaching ridge of Devonian gabbro.

54.0 Turn off Route 11 at Co-op Centre to power plant.

STOP 6 – The Lower Devonian (Helderberg) Dalhousie Group consists of shallow-water, fossiliferous shales and limestone with intercalated andesites, basalt flows, tuffs, etc. Basal calcareous shales are poorly exposed, along strike trilobites of Helderberg (Gedinnian) age have been found. The palagonite tuff above contains a zeolite (analcime) assemblage (Mossman and Bachinski, 1972). Columnar jointing and (rare) amethystine-quartz-filled geodes are exhibited in the basic flows, which probably originated from vents at Dalhousie and Sugar Loaf Mountain.

55.5 Back on Route 11. Proceed through Dalhousie.

56.5 Devonian andesites.

56.7 Ferry road to Gaspé. Upper Devonian Escuminac Formation across bay.

59.1 to
59.4 Devonian volcanics dipping to north.

71.7 Sugar Loaf Mountain overlooking Campbellton ahead.

74.6 South end of Interprovincial Bridge to the Gaspé.

OVERNIGHT in Campbellton (40 Winks Motel).

SATURDAY, OCTOBER 13, 1973

0.0 Campbellton.

0.9 Turn right into lumber yard and park vehicles.

STOP 1 – Walk down to shore and examine Campbellton Formation (Middle Devonian) with fish (*Cephalaspis, Climatius, Cheiracanthus, Gyracanthus, Doliodus, Mesacanthus,* etc.) and plant (*Psilophyton, sensu lata,* Wm. Forbes, pers. comm.) remains, and ostracods interbedded in tuffs, etc.

6.0 Tide Head. Turn off onto Route 17 (left). Glaciofluvial terraces.

11.0 Flenlevit. Devonian basalts, etc. from ca. Mile 8.0.

11.7 STOP 2 – Limestone-pebble conglomerate, orange felsite of Upper Silurian or Lower Devonian age.

15.0 STOP 3 – DANGEROUS right-angle bend; park just before it. Pentamerid (*Conchidium*?) zone; probably Middle or Upper Silurian.

15.5 Rafting Ground Road. Possible detour to Restigouche River and Matapedia Group.

23.9 Upsalquitch River crossing.

25.5 STOP 4 – Deformed (near fault) basal Silurian (?) sandstone and shale, with (0.5 Miles farther) smashed and contorted Matapedia argillite. Continue Route 17 to St. Leonard and Route 2 (Trans-Canada Highway) to Fredericton.

TRIP A-8 and B-7, by H. V. Donohoe, Jr., The University of New Brunswick.

ACADIAN OROGENY IN COASTAL SOUTHERN NEW BRUNSWICK

INTRODUCTION

This excursion visits an area underlain by Upper Silurian to Lower Devonian rocks that has been affected by the Acadian Orogeny (Fig. 1). Generally, these rocks are distributed in sections bounded by northeast trending faults. Approximately 12 km. southeast of St. George at the coast, the Precambrian Coldbrook Group crops out, (G.S.C. Map 1094A), exposing primarily tuffaceous and argillaceous rocks intruded by alaskite and metadiabase dykes and sills. West of the excursion area a large thickness of Middle to Upper Silurian extrusive and clastic rocks and Lower to Middle Ordovician slates underlies the north side of Passamaquoddy Bay. The contact is interpreted as a faulted disconformity (Ruitenberg, 1968). All of these rocks (Ruitenberg, 1968) and the Precambrian (Helmstaedt, 1968) rocks have been deformed during the Acadian Orogeny. Subsequent to the deformation, the St. George calc-alkali complex was intruded across the Acadian structural trend and into the Ordovician to Lower Devonian rocks.

The results of recent work indicate that the excursion area is the only area in coastal southern New Brunswick where a complete chronological sequence of Acadian orogenic deformations is visible. Rast and Grant (1973) have demonstrated a strong late Paleozoic Orogeny that affects rocks approximately 20 km to the east. Working in Maine near southern New Brunswick, Westerman (1973) finds that the Pocamoonshine Gabbro-Diorite intrudes previously deformed, non-fossiliferous rocks which are considered to be Silurian in New Brunswick. K-Ar age dates of 408 ± 14 and 423 ± 24 m.y. were obtained from biotite and hornblende, respectively. Taconian movements certainly disturbed some of the rocks to the west, while those rocks to the east were affected by a late Paleozoic event. Within this new structural framework, the excursion area becomes the only definite section of the Acadian orogeny on the south coast of New Brunswick.

STRATIGRAPHY AND PALEOENVIRONMENT

Approximately 5000 m. (apparent thickness) of Upper Silurian to Lower Devonian rocks crop-out in the St. George area (Fig. 1).

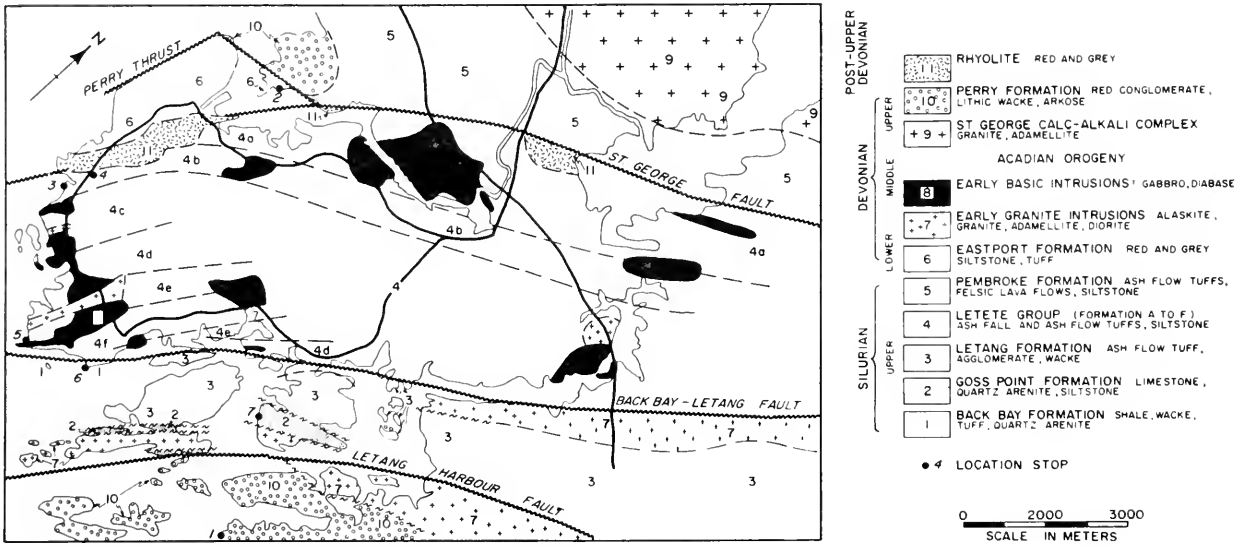


Fig. 1 Geologic Map with stop locations.

These are divisible into six rock-stratigraphic units and are listed in the accompanying Table 1 along with their lithology, thickness and age.

A brief glance at Table 1 reveals the extensiveness of volcanic activity recorded in these rocks. The dominant type of activity from petrographic investigations appears to be ash-flow and ash-fall tuffs, crystal tuffs, and agglomerates (some of which may be lahars). That volcanic activity was probably in close proximity is suggested by the presence of accretionary lapilli tuff in formation 4B of the Letete Group and the lower member of the Eastport Formation (6). According to Moore and Peck (1962) accretionary lapilli form like hailstones and indicate a proximity of 10 km. or less from the vent.

Table 1 - Table of Stratigraphy

Map Unit	Rock Stratigraphic Unit	Lithology	Apparent Thickness	Stop Number
10	Perry Formation (Upper Devonian)	Red-brown polymict conglomerate, coarse-grained red lithic arenite and arkose; minor amounts of siltstone. Some basalt flows and tuffs.	NW 90 m SE 2000 m	1,2
6	Eastport Formation (Gedinnian)	Generally thin-bedded, red to olive-gray quartz wackes, crystal and lithic tuffs at base, coarse red-brown polymict conglomerate at top.	400 m	2
5	Pembroke Formation (Pridoli)	Ash-flow tuffs, rhyolite lava flows, ash-fall tuffs; red-brown quartz wacke and siltstone.	1420 m	-
4	Letete Group (Wenlock to Pridoli)	Divisable into six formations. Dark gray, thin bedded siltstones at top and bottom; remaining thickness is predominantly ash-flow and ash-fall tuffs, and lava flows with a thick clastic formation of quartz wacke.	2400 m	3,4 5,6
3	Letang Formation (Late Llandovery to Ludlow)	Rhyolitic ash-flow tuffs and lava flows; agglomerate and volcanic wackes; basalt flow; lithic tuff containing clasts of limestone.	600 m	-
2	Goss Point Formation (Late Llandovery to Wenlock)	Three Members. Oldest is limestone and dolomite of Letang Limestone. Middle member composed of quartz arenite and quartz wacke. Calcareous shales and siltstones overlie.	850 m	7
1	Back Bay Formation (Late Llandovery, C4-C5)	Quartz arenite and wacke and siltstone at base. Tuff and agglomerate overlain by calcareous siltstone, basalt lava flow, red shales, quartz wackes, and conglomerates.	300 m	6

Interspersed in the column are clastic rocks most of which are poorly sorted wackes. The notable exception is the possible carbonate bank represented by the Letang Limestone Member of the Goss Point Formation and a high energy deposit of well sorted, fairly coarse-grained quartz arenite of the middle Member, Goss Point Formation.

Pre-Acadian orogenic conglomerates are few in number and occur in the upper part of the Back Bay Formation, the middle part of the Goss Point Formation, the Letang Formation, and the upper member of the Eastport Formation. In all of the conglomerates except the Letang Formation, basal red and gray siltstone, red rhyolite, diorite and andesite are ubiquitous. Quartz

porphyry rhyolites are dominant in the Letang Formation conglomerates and indicate a certain amount of contemporaneous erosion of the Letang Formation rhyolitic ash-flow tuffs and lava flows. No clasts have been found with a previously existing tectonic fabric although some primary fabrics have been observed. Intraformational conglomerates composed of quartz wacke clasts are common in the Eastport Formation and most probably represent the slumping of pre-existing semi-lithified beds.

Conglomerates in the Perry Formation are the most abundant lithology and contain clasts of most of the pre-upper Devonian rocks. Many of these clasts are from the St. George calc-alkali complex and many clasts have the strong L-S tectonite fabric of the D_1 Acadian deformation. Locally at Stop 1 (Pea Point), the Perry Formation contains clasts of twice deformed rhyolites and siltstones. Overprinting the D_1 fabric in the clasts are either kink bands or a finely developed crenulation cleavage. Since the Perry Formation is characterized by an abundance of conglomerates (some of which are dominated by a certain rock type along specific horizons), abrupt lateral facies changes (Helmstaedt, 1968), and some massive breccia layers (locally present on the north shore of Passamaquoddy Bay) where boulders 1 to 6 m. in length are surrounded by a very poorly sorted red matrix, it probably represents a high energy environment of coalescing alluvial fans.

INTRUSIVE IGNEOUS ACTIVITY

Intrusive igneous rocks account for a large volume of the total rock as seen in Fig. 1. The several phases and age of mafic and felsic intrusions are tabulated in Table 2.

STRUCTURAL GEOLOGY AND METAMORPHISM

The Acadian Orogeny consists of four phases of deformation and has affected the Precambrian rocks 12 km. southeast of St. George and all of the Upper Silurian to Lower Devonian rocks shown in Fig. 1. The first (D_1) and second (D_2) phases were major fold generating events while D_3 and D_4 produced kink band deformations important only on an outcrop scale. Table 3 gives the results of the detailed analysis of the four phases of Acadian Orogeny.

Metamorphism — Synchronous with the D_1 deformation was an episode of Barrovian type metamorphism that reached the quartz-albite-epidote-biotite subfacies of the greenschist facies. Typical assemblages in pelitic rocks are quartz-chlorite-musco-

Table 2 - Intrusive Igneous Activity

ASSOCIATION	NAME, MINERALOGY, TEXTURE	AGE	STOP NUMBER
Late Basic Activity	Clinopyroxene Diorite dykes; <1 mm. crystals of clinopyroxene rimmed by hornblende, andesine and chlorite; Sub-ophitic texture.	Intrudes St. George Complex and across the St. George fault. post-Mississippian	-
Late Felsic Activity	Red and gray porphyritic rhyolite stocks and dykes; fine-grain (<0.4 mm.) quartz, potassium feldspar, albite and some muscovite phenocrysts in micro-crystalline groundmass.	Intrudes across the St. George Fault. Cross-cuts S_1 in Back Bay Formation. Probably post-Mississippian.	4,6
Middle Felsic Activity	St. George Calc-Alkali Complex; Biotite adamellite; biotite, potassium feldspar, oligoclase, quartz; hypidiomorphic granular texture; Crystals <2 mm.	Intrudes across Acadian trend (D_1-D_2). Pebbles are in Perry Fm. Middle Devonian. K-Ar 380 m.y. (Biot.)	6
Middle Basic Activity	Clinopyroxene and hornblende diorite dykes; hornblende rimming hornblende or clinopyroxene remnants, plagioclase (An_{30}-An_{40}) chlorite; subophitic texture; Crystals 0.5-2 mm.	Slightly to greatly altered. Post D_1 or D_2. Lower to Middle Devonian.	
Early Basic Activity	Hornblende diorite stocks, sills and dykes; hornblende (occasionally rimming clinopyroxene), chlorite, epidote, plagioclase (An_{10}-An_{52}), some blue-green (actinolite) amphibole rimming hornblende or pyroxene; diabasic to sub-ophitic texture unless destroyed by D_1 L-S tectonic fabric; Crystals 0.5 to 2 mm; unusual ophitic textured pods (~2 cm) of same mineralogy as remainder of diorite locally developed.	Intrudes Blacks Harbour. Granite and is cleaved by S_1. Extensively altered by metamorphism. Lower to Middle Devonian.	4
Early Felsic	Blacks Harbour Granite, stocks, dykes; alaskite to adamellite; variable mineralogy; generally quartz, potassium, feldspar, chlorite, hornblende, muscovite and/or biotite and plagioclase (An_5 to An_{15}); Crystals 0.5-2 mm. hypidiomorphic granular texture.	Contains xenolith of Letang Formation. Extensively altered by cataclasts during D_1. Lower to Middle Devonian.	
	Orange-tan rhyolite dyke. Phenocrysts of quartz and potassium feldspar in micro-crystalline groundmass.	Cleaved by S_1 and intruded by Blacks Harbour Granite. Lower to Middle Devonian.	

vite-biotite and quartz-muscovite-biotite, while the hornblende metadiabase has varying assemblages of chlorite-hornblende (actinolite)-epidote-albite (oligoclase). The lack of truly typical assemblages for basic rocks of this subfacies is interpreted as a function of when a particular basic rock was intruded during the D_1 deformation-metamorphism. Those basic rocks intruded prior to the commencement of D_1 show an L-S tectonite fabric and the typical basic assemblage of the quartz-albite-epidote-biotite subfacies while other basic intrusions intruded during or after D_1 show varying structural and metamorphic affects.

Metamorphism (quartz-albite-epidote-chlorite subfacies) con-

Table 3 - Deformations of the Acadian Orogeny

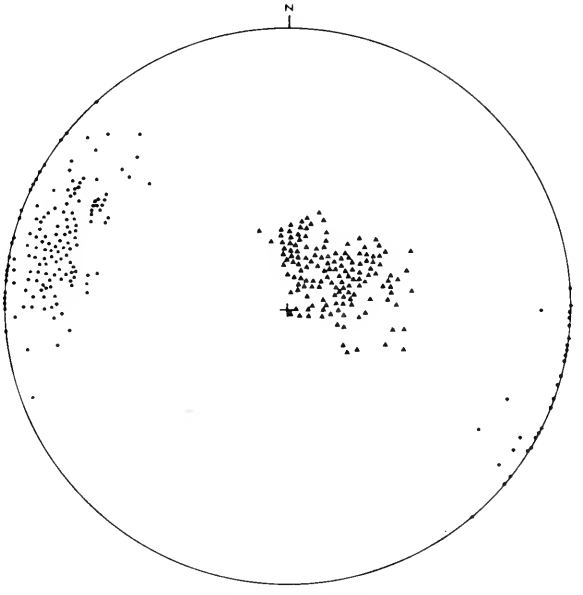
	UPPER SILURIAN	LOWER DEVONIAN
D_1 Folds	Isoclinal to tight, upright axial surfaces, steep NE plunging hinge lines. Wave lengths 8-10 km (maximum). (See Fig. 3)	No F_1 folds present.
Cleavage	Strongly developed NE trending S_1, accentuated by biotite, chlorite muscovite. Strong mineral clast lineation on S_1. Clastaclastic deformation texture imposed on most rocks.	Well developed slatey-cleavage. Accentuated by muscovite and chlcrite.
Strain	Deformation symmetry 0>k>1. Several directions of boudinage. From clasts and crystals average elongation of 40 to 120% and 40 to 60% shortening. Orientation of D_1 strain ellipse is the average values of S_1 and I_1 orientations in Fig. 2. Regionally an irrotational, homogeneous deformation (Fig. 2).	Deformation symmetry 0>k>1. From chlorite maygdules in diabase dyke, 70% elongation and 50% shortening.
D_2 Folds	Tight to close, upright, moderate to steep NE and SW plunging hinge lines. Maximum wavelength of 2-4 km. Some interference structure.	Open to close, inclined (vertical western limb), shallow NE and SW plunging hinge lires. Maximum wavelength of 1 to 2 km. Many folds broken by high-angle reverse faults parallel to axial surfaces. No cleavage.
Cleavage	Locally well-developed crenulation cleavage with some chlorite and muscovite nucleated in axial surfaces.	No cleavage.
Strain	Unable to calculate.	Shortening of Eastport Fm. of approx. 20% by unfolding F_2 folds.
D_3*	Kink bands. Steep plunging NE and SW hinges on S_1 surface. Kink band zones dip>45° NE and SW. Found as single kinks, "crenulation cleavage", or in conjugate pairs. Overprints F_2 folds locally.	Not present.
D_4*	Kink bands. Shallow plunging NE and SW hinges on S_1 surface. Kink band zones dip<45° NE and SW. Found as single kinks and "finely developed crenulation cleavage". Overprints F_3 kink bands.	Kink bands. Shallow plunging SW hinge lines. Axial surfaces dip shallowly westward. Present as single kink bands.

* Each kink band of F_3 and F_4 represents 10 to 15% shortening.

tinued during D_2 as shown by the nucleation and growth of very-fine-grained chlorite and muscovite in the axial surfaces of S_2 crenulation cleavage. Basic intrusions of middle phase basic generation (Table 2) have hornblendes or clinopyroxene altering to chlorite; however, the plagioclase has a high An content (An30 to An40).

Age and Correlation of Deformation (Table 3) – The first deformation in the Upper Silurian is synchronous with that in the Lower Devonian as demonstrated by the development of a metamorphic accentuated S_1 cleavage. In each area the S_1 cleavage is overprinted by F_2 folds. Although metamorphism was present during D_2 time, only some of the F_2 folds have a metamorphic axial planar cleavage. Thus the widespread metamorphic enhancement of S_1 provides the means of structural correlation between Upper Silurian and Lower Devonian rocks.

Precambrian rocks are deformed by two major fold generation events (Helmstaedt, 1968) and appear to have the same D_1 metamorphic, L-S tectonite fabric that the Upper Silurian rocks have (Brown and Helmstaedt, 1970; Donohoe, 1973a). Fig. 2 is a comparison of D_1 structural elements from the Letete Group and the Coldbrook Group (Precambrian). At least the first phase of deformation in the Precambrian is attributable to the Acadian.



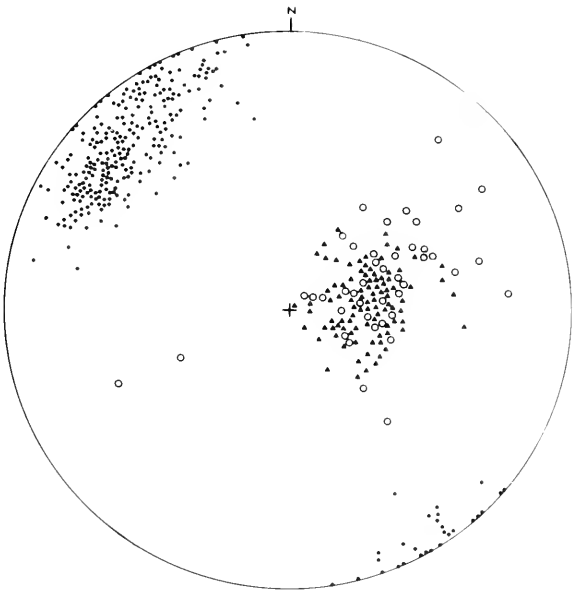


Fig. 2 A comparison of the D_1 Acadian structural elements in Silurian and Precambrian rocks.

The Acadian Orogeny is older than the Perry Formation which has clasts of St. George Complex rocks and clasts containing two phases of deformation. The Perry Formation does not have any kink bands generated although the anisotropy conditions are favourable. Lithologic correlation with the type section in Perry, Maine suggests an Upper Devonian age.

The few K-Ar dates help in dating the age of the orogeny. Helmstaedt (1968) reports a date of 369 ± 20 m.y. from actinolite in the D_1 L-S fabric. Dates from biotite in the St. George Complex give 380 m.y. Since both of these dates may represent the onset of the thermal/pressure threshold to retain Ar in the system, they should be interpreted as upper limits. The Acadian Orogeny from all available data probably culminated with the D_1 and D_2 deformations at the beginning of Middle Devonian time.

Later Deformation — The cleavage observed in the Perry Formation at Stop 1 represents a deformation that is sufficiently strong to rotate non-spherical clasts into the cleavage plane. This deformation ends at the western limits of the southeastern Perry Formation outcrop. At Stop 2 the Perry is only gently tilted at 15° to the south. The observed deformation in the vicinity of Stop 1 is post-Upper Devonian and probably represents the late Paleozoic Orogeny of Rast and Grant (1973).

Faulting — Major northeast trending faults form prominent lineaments in the excursion area. Between them lie rocks of uniform age and structural style. The latest movement on these faults is most probably dip slip with the southeast side up as indicated by fractures in the rocks immediately adjacent to the faults (Helmstaedt, 1968; Donohoe, 1973b). Faults trending westerly and northerly have right-lateral and left-lateral movement, respectively, and are the youngest faulting events.

The age of movement of these faults from stratigraphic offsets is definitely post-Upper Devonian on the St. George fault and post-Lower Carboniferous on the Beaver Harbour fault (the Belleisle-Lubec fault of Brown and Helmstaedt, 1970) 12 km. southeast of St. George village at Beaver Harbour village. W. van de Poll (personal communication, 1972) reports that extensions of these faults near Shediac, N. B. offset beds of Westphallian D age. Garnett (1972) suggests that the Beaver Harbour fault may be as young as Triassic since it offsets a probable Triassic diabase dyke.

While all of the northeast trending faults seem to be of the same age, the only cross-cutting relationship between faults is

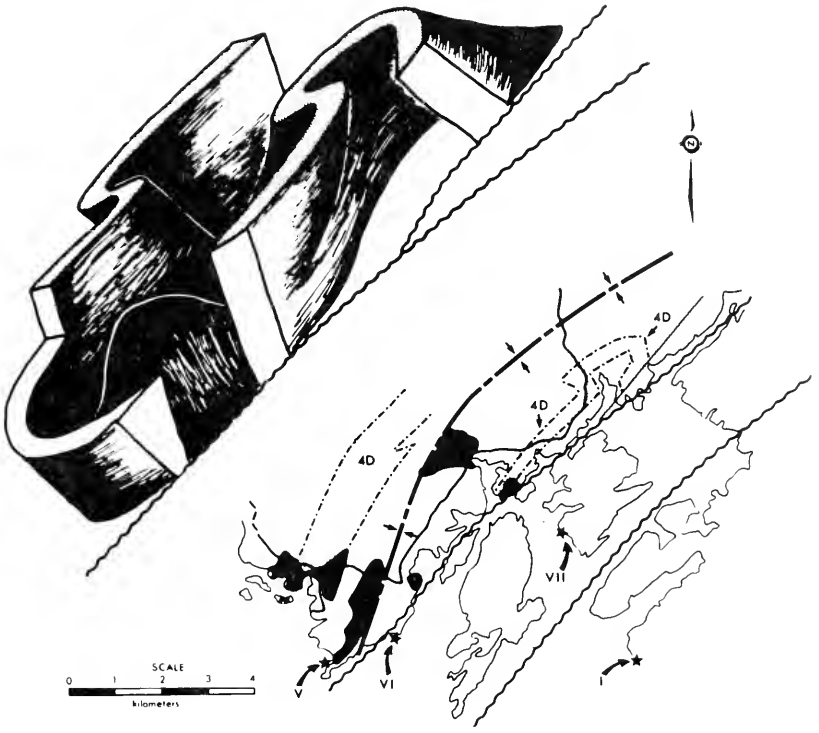


Fig. 3 Three dimensional diagram of formation D (4D) of the Letete Group. The fold is a complete F_1 syncline with doubly plunging minor folds and represents the overall structure of the Letete Group. Note that the fold is truncated by the Back Bay-Letang Fault.

present in the excursion area near Stop 2 where the St. George fault truncates the trend of the Perry thrust fault.

SUMMARY

The excursion area presents a complete statement of the Acadian Orogeny. It appears to be the only area where all four phases of deformation are present along the coast of southern New Brunswick. The dating of the Acadian Orogeny is exceptionally well documented by radiometric and stratigraphic data. The area provides an opportunity to study the extensive deposits of Upper Silurian to Lower Devonian volcanic rocks as well as six phases of intrusive igneous rocks.

LOGS AND STOPS

(All stops are located on Map 21G/2W, St. George)

STOP 1 – Pea Point, Blacks Harbour. Perry Formation. Military Grid Reference (MGR) 727896. Post Acadian cleavage. Clasts representing Acadian deformations.

STOP 2 – Pickering's House, mouth of Magaguadavic River. Perry Formation. MGR 652979. Nature of the Perry Formation. Perry Thrust. Eastport Formation and its deformation styles.

STOP 3 – Cove, due east of Upper Green Point. Letete Group. MGR 642926. Ash flow tuffs. D_1 deformation elements.

STOP 4 – Driveway to Simpson's House. Letete Group. MGR 644931. Contact of post-Mississippian Red Rhyolite with Letete Group. Sills of early basic intrusions.

STOP 5 – Greens Point, Hoyt House, Letete Group. MGR 665895. Nature of the four Acadian deformations.

STOP 6 – Back Bay Beach. Back Bay Formation. MGR 675901. Outcrop of Back Bay-Letang Fault. Comparison of structural styles across faults.

STOP 7 – Letang Wharf. Goss Point Formation, Letang Limestone Member. MGR 712922. Intense D_1 and D_2 deformations in limestone.

TRIP A-9, by A. A. Ruitenberg, New Brunswick Department of Natural Resources.

TECTONIC EVOLUTION AND MINERAL DEPOSITS OF THE NORTHERN APPALACHIANS IN SOUTHERN NEW BRUNSWICK

INTRODUCTION

The complex tectonic history of the Northern Appalachians, in Southern New Brunswick, is reflected in a great variety of mineral deposits, which occur in several distinct belts. In general, the field trip emphasizes contrasting geologic environments and structures as related to metallization (Fig. 1).

CALEDONIA BELT

The oldest rocks containing sulphide deposits of economic interest occur in the Caledonia Belt (Fig. 2), which extends for about 160 kilometers along the Bay of Fundy Coast, in Southern New Brunswick. This area is mainly underlain by late Precambrian volcanic and sedimentary rocks (Coldbrook Group), in part overlain by Cambrian, possible Silurian and Carboniferous sedimentary and minor volcanic rocks. The Coldbrook Group consists mainly of andesitic, dacitic and rhyolitic flows, tuffs and breccias, which have been intruded by granitic, dioritic and gabbroic plutons. In the southeastern part of the belt, arkosic and quartzitic clastic sedimentary rocks (shallow water environment) are intercalated with the lower part of the volcanic sequence, whereas poorly sorted volcanogenic sedimentary rocks are abundant higher in the section. Volcanic flows and ignimbrites (terrestrial) predominate in the northwestern part of the belt.

The Coldbrook Group in the Loch Alva — Kingston Peninsula area (Kennebecasis Deformed Zone), adjacent to the Palaeozoic Mascarene-Nerepis Belt (see next section) have been subjected to intense polyphase deformation probably during the Acadian (Middle Devonian) Orogeny (Ruitenberg **et al.**, 1973). Late Precambrian and Early Carboniferous (and/or Late Devonian) rocks in a broad belt, along the Bay of Fundy, have been deformed by intense cataclasis (Fundy Cataclastic Zone). This deformed zone conforms roughly to a northeast trending upwarped belt, defined by a well developed penetrative cleavage. Effects of at least one, and locally two, subsequent deformation phases have been re-

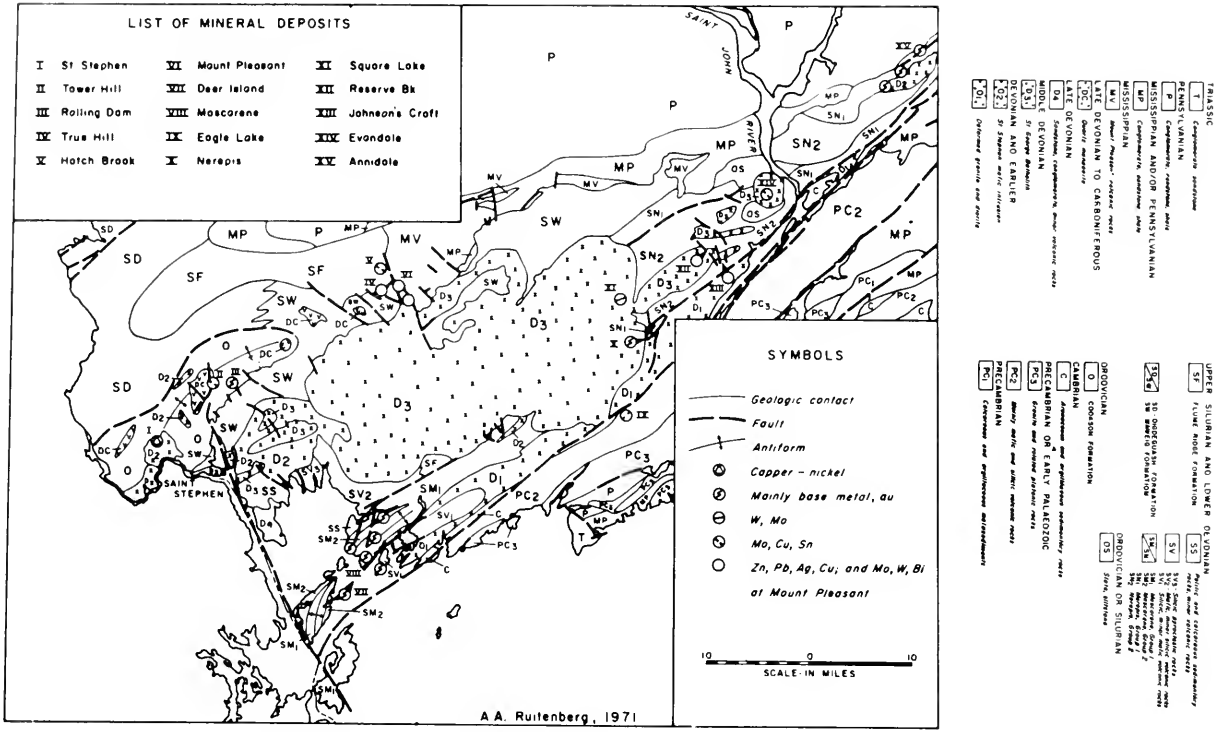

LIST OF MINERAL DEPOSITS
I St Stephen
II Tower Hill
III Rolling Dam
IV Trus Hill
V Hatch Brook
VI Mount Pleasant
VII Deer Island
VIII Moscarene
IX Eagle Lake
X Nerepis
XI Square Lake
XII Reserve Bk
XIII Johnson's Croft
XIV Evandale
XV Annidale
SYMBOLS
Geologic contact
Fault
Antiform
Copper - nickel
Mainly base metal, au
W, Mo
Mo, Cu, Sn
Zn, Pb, Ag, Cu; and Mo, W, Bi at Mount Pleasant
SCALE-IN MILES
SAINT JOHN RIVER
SAINT STEPHEN
A.A. Ruitenberg, 1971
TRIASSIC
PENNSYLVANIAN
MISSISSIPPIAN AND/OR PENNSYLVANIAN
MISSISSIPPIAN
LATE DEVONIAN TO CARBONIFEROUS
LATE DEVONIAN
MIDDLE DEVONIAN
DEVONIAN AND EARLIER
UPPER SILURIAN AND LOWER DEVONIAN
FLUME RIDGE FORMATION
SD-DIDDEGUASH FORMATION
SW MAMEIG FORMATION
ORDOVICIAN
COOSSON FORMATION
CAMBRIAN
PRECAMBRIAN OR EARLY PALAEOZOIC
PRECAMBRIAN
ORDOVICIAN OR SILURIAN

Fig. 1

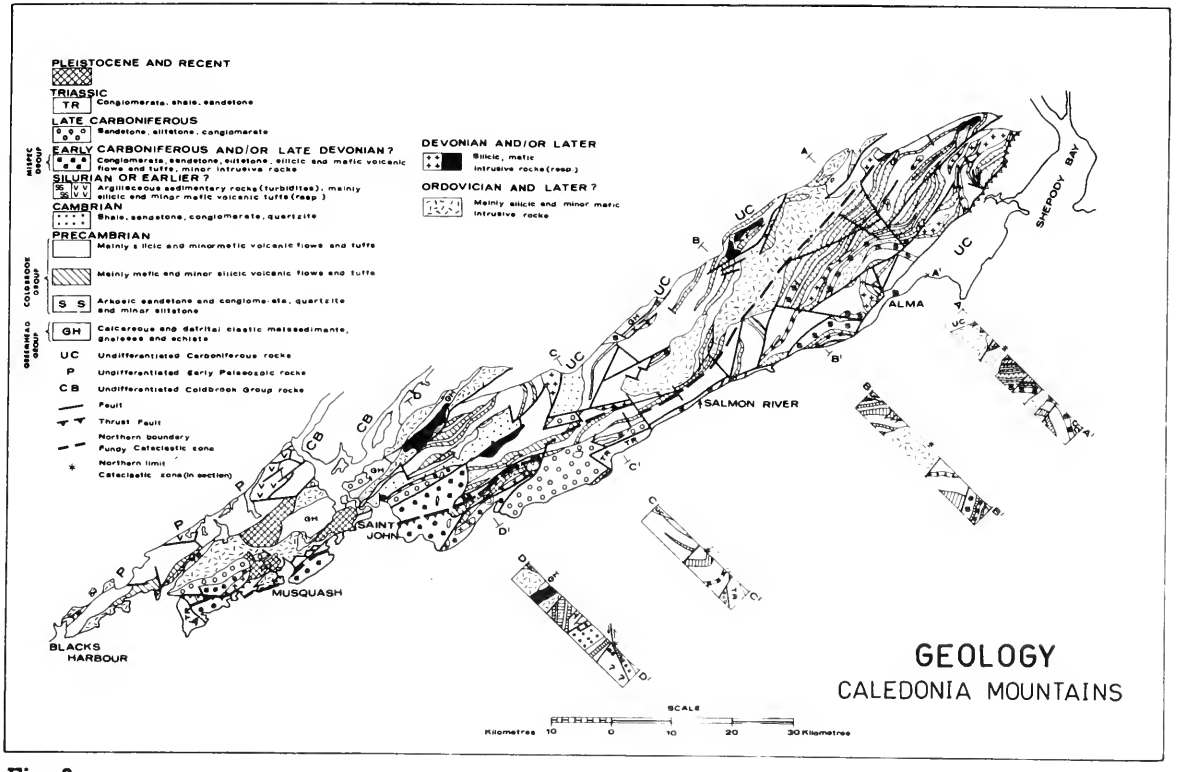

PLEISTOCENE AND RECENT
TRIASSIC
TR Conglomerate, shale, sandstone
LATE CARBONIFEROUS
Sandstone, siltstone, conglomerate
EARLY CARBONIFEROUS AND/OR LATE DEVONIAN?
Conglomerate, sandstone, siltstone, silicic and mafic volcanic flows and tuffs, minor intrusive rocks
SILURIAN OR EARLIER?
Argillaceous sedimentary rocks (turbidites), mainly silicic and minor mafic volcanic tuffs (resp.)
CAMBRIAN
Shale, sandstone, conglomerate, quartzite
PRECAMBRIAN
Mainly silicic and minor mafic volcanic flows and tuffs
Mainly mafic and minor silicic volcanic flows and tuffs
S S Arkosic sandstone and conglomerate, quartzite and minor siltstone
GH Calcareous and detrital clastic metasediments, gneisses and schists
UC Undifferentiated Carboniferous rocks
P Undifferentiated Early Palaeozoic rocks
CB Undifferentiated Coldbrook Group rocks
Fault
Thrust Fault
Northern boundary
Fundy Cataclastic zone
Northern limit
Cataclastic zone (in section)
DEVONIAN AND/OR LATER
Silicic, mafic intrusive rocks (resp.)
ORDOVICIAN AND LATER?
Mainly silicic and minor mafic intrusive rocks
MUSQUASH GROUP
COLDBROOK GROUP
GREENHEAD GROUP
SHEPODY BAY
ALMA
SALMON RIVER
SAINT JOHN
MUSQUASH
BLACKS HARBOUR
GEOLOGY
CALEDONIA MOUNTAINS
SCALE
Kilometres 10 0 10 20 30 Kilometres

Fig. 2

cognized. The penetrative deformation probably resulted from upwarping or bending (under a lithostatic load), which was produced by vertical movements of basement blocks underlying deformed layers (Ruitenberg et al., 1973). Numerous high angle reverse and normal dip-slip faults, and locally low angle thrusts cut across both the late Precambrian and younger rocks. Latest movements along these faults postdate the cataclastic deformation.

Mineral deposits of economic interest occur mainly in the southeastern part of the Caledonia area, which is underlain by highly deformed mafic and silicic tuffs, and associated volcanogenic sedimentary rocks (shallow water environment). Sulphide deposits of two distinct ages have been recognized (Ruitenberg et al., 1972). The Teahan and Lumsden deposits are examples of pyrite-copper-zinc sulphide deposits, which are the earliest known in the area. Small amounts of copper were mined from the Teahan deposit around 1880. The host rocks are composed of intensely sheared and altered andesitic tuff with minor intercalated rhyolite tuff and associated volcanogenic sedimentary rocks. Sills and dykes composed of diabase, diorite and granite occur along the footwalls of these deposits. The deposits are enveloped by a dark green chloritic alteration zone, which is thickest along the hanging wall. The mineralized and chloritized zones are enveloped by a wide zone of silicification, talcose and micaceous alterations. Clay minerals, epidote and calcite are also common. It is notable that pyrite is abundant throughout the entire altered zone. Both the altered host rocks and surrounding country rocks show a well developed penetrative cleavage. Intense slip has occurred roughly parallel to this cleavage. This produced chevron folds or flexures, which mostly plunge in the regional dip direction of the cleavage. Base metal sulphides are generally concentrated in axial regions of these cross folds, within the intensely altered, pyrite-rich tuffaceous horizons.

Deposits related to the final metallization episode are mainly composed of copper sulphides with locally abundant tennantite and tetrahedrite, which occur in brecciated and fractured quartz-carbonate veins. These veins post date the late stage cross folds and they cut across both late Precambrian and early Carboniferous rocks. Examples are the "Vernon" Copper deposit, which was mined around 1865, and several mineralized fracture zones in the Black River and Musquash areas (Ruitenberg, 1969, 1970). The more prominent of these deposits appear to be related to faulted unconformities between Coldbrook Group rocks and Carboniferous sediments.

MASCARENE – NEREPIS AND ROLLING DAM BELTS

The Mascarene-Nerepis Belt extends from the Passamaquoddy Bay area to the northeast into the Annidale area. It is separated by major faults from the Caledonia Belt to the southeast. The Rolling Dam Belt extends from St. Stephen to the northeast into the Mount Pleasant area (Ruitenberg, 1967, 1972).

The Mascarene-Nerepis Belt is chiefly underlain by intensely deformed Silurian to Lower Devonian andesitic and rhyolitic flows and tuffs, siltstones and slates (shallow marine environment). In the northeastern part of this belt these rocks are locally conformable or in faulted contact with Ordovician graphitic slate, siltstone (generally rich in iron sulphides and oxides), greywacke, mafic and silicic volcanic rocks. The Rolling Dam Belt consists largely of Ordovician graphitic slate overlain by Upper Silurian to Lower Devonian greywacke and slate. Both belts underwent polyphase deformation during the Acadian (Middle Devonian) Orogeny (Ruitenberg, 1967, 1968, 1969, 1970, 1972) and Brown and Helmstaedt (1970). The main penetrative phase of this deformation resulted from a northwest-southeast shortening and it was followed by emplacement of a large batholith composed mainly of silicic and minor mafic plutonic rocks.

Nickel-copper sulfide deposits in gabbro and norite, at St. Stephen in the Rolling Dam Belt, are believed to be the earliest in this area, but the time of emplacement is not certain. The earliest base metal deposits occur in dilatant structures, related to late phase chevron folds, in the Mascarene-Nerepis Belt. Copper sulfides predominate where these structures occur in intensely altered andesitic tuffs, whereas zinc sulfides are most abundant in calcareous siltstones and slates, and rhyolite tuff. Economically the most interesting of these deposits occur in the Annidale-Nerepis area (Ruitenberg, 1972). Some small gold-arsenopyrite-quartz deposits occur in similar dilatant structures in the Rolling Dam Belt, but no base metal deposits are known to be associated with these structures in this belt. The intimate relationship of the various types of metallic minerals to certain well defined rock types, suggests that the metallic sulfides were originally deposited with the hostrocks and subsequently remobilized. Heat and hydrothermal fluids, generated by emplacement of the pluton, were probably responsible for the remobilization of the metallic minerals.

The latest deposits were formed during early Carboniferous time and are associated with north-northwest trending zones of intense wrench and block faulting (rifts), close to the contact of

the major batholith. The base metal tin-tungsten-molybdenum deposits at Mount Pleasant are the largest known of these deposits and occur in intensely fractured and silicified rhyolitic fragmental rocks (Ruitenberg, 1967, 1972; Parrish and Tully, 1971). Numerous smaller tin, silver-base metal and copper-molybdenum deposits occur in and along silicic stocks and dykes, which were emplaced during this period.

MONCTON – SUSSEX BELT

Numerous interesting mineral deposits occur in Carboniferous rocks of southeastern New Brunswick. Limited time available for this field trip does not permit intensive examination of the geologic environment of these deposits. The following is a brief resume.

Gypsum has been produced at Hillsborough for many years. Limestone is being quarried at Havelock. Great thicknesses of salt and potash have been intersected by diamond drilling in the Penobsquis-Plumweseep areas near Sussex. Economically interesting amounts of celestite and barite have been discovered at Upper Dorchester. Albertite (solid asphalt) was formerly mined at Albert Mines. The Stony Creek oil field is situated about five miles north of this occurrence.

The most interesting metallic mineral deposits are cupriferous (chalcocite and malachite) sandstones in the Dorchester, New Horton and Goshen areas. These deposits appear to be associated with the first grey (channel) sandstone sequence overlying Hopewell red beds (van de Poll, 1973).

SCHEDULE AND DIRECTIONS

October 11:

P.M.

(1) **Lecture Tectonic History and Mineral Deposits, Northern Appalachians** in Southern New Brunswick, Hopewell Rocks Motel, 8 P.M.

(2) The itinerary can be modified to meet specific interests of participants.

October 12:

A.M.

(1) Albert Mines – brief stop at albertite occurrence and nearby outcrop with numerous palaeoniscid fish skeletons first discovered by Greiner (1961).

(2) Old Teahan Mine – intensely altered and mineralized rocks at the old mine site will be compared with nearby country rocks. Effects of penetrative deformation and subsequent deformation will be demonstrated.

(3) Bennett Lake – rhyolitic and andesitic tuffs of the Coldbrook Group are well exposed along Highway 114 in this area. The well developed penetrative cleavage in these rocks was produced by intense cataclasis (Fundy Cataclastic Zone). The well developed crenulation cleavage resulted from a second deformation.

P.M.

(4) Old Annidale Copper Mine – Effects of cross-folding on the distribution of copper sulphides in andesite tuffs will be demonstrated. It is notable that pyrite-rich slates on the footwall of the deposit have been similarly deformed, but contain no copper sulphides.

October 13:

A.M.

(5) Black River – sedimentary and volcanic rocks of the Mispec Group (Early Carboniferous or Late Devonian) are to the north in faulted contact with Coldbrook (Late Precambrian) volcanics. These rocks form part of the Fundy Cataclastic Zone and have been affected by two phases of deformation. An interesting occurrence of copper sulphides is exposed in fractured Mispec rocks close to this faulted contact. Further north in this section, deformed Coldbrook rocks have been thrust over sedimentary rocks of possible Silurian age, which show no effects of penetrative deformation.

A.M. – P.M.

(6) Mount Pleasant – Cross-cutting relationships of various rock types in this volcanic complex will be examined. Effects of several metallization and alteration phases will be shown.

P.M.

(7) Digdeguash River at Rolling Dam (7a) and Tryon (7b) Typical Ordovician and Upper Silurian – Lower Devonian facies will be compared. Effects of polyphase Acadian (Middle Devonian) deformation on various lithologies will be demonstrated.

TRIP A-10 and B-8, by P. Stringer and R. J. Wardle, University of New Brunswick.

POST-CARBONIFEROUS AND POST-TRIASSIC STRUCTURES IN SOUTHERN NEW BRUNSWICK

INTRODUCTION

The field trip is designed to draw attention to structures in Carboniferous and Triassic rocks of the Maritime Appalachians. Post-Carboniferous and Post-Triassic deformations are distinguished. The style and intensity of deformation of Post-Carboniferous (Pre-Triassic) structures differ between the Mississippian (or Pennsylvanian) Mispek Group and the Pennsylvanian Lancaster Formation, and also vary from place to place within each formation. Folds of varying magnitude are present in the Triassic rocks.

At Lepreau Falls (Stop 1) bedding attitudes in the Triassic Lepreau Formation indicate a minor NE-SW syncline. The fold

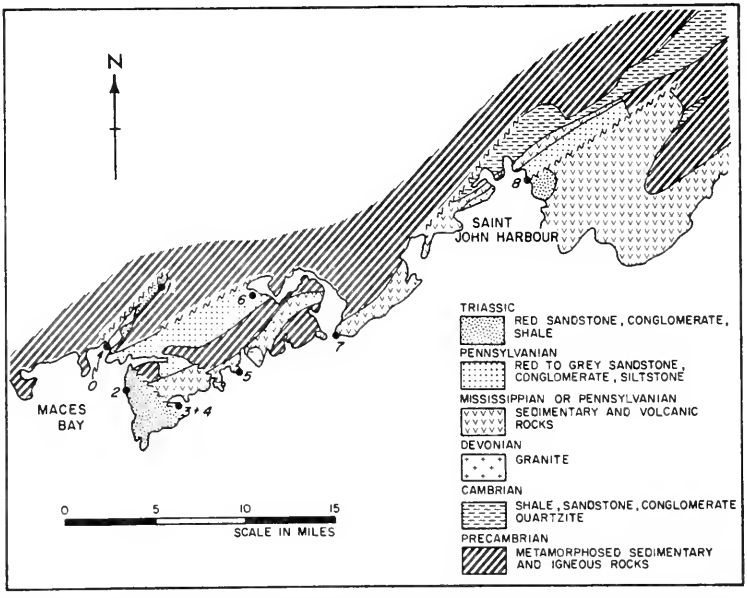


Fig. 1 Geological Map of Saint John Area, New Brunswick. Based on compilation by R. R. Potter, 1968.

trends parallel to the faulted contact between the Triassic beds and Precambrian rocks to the northwest (Fig. 1). The fold may be related in origin to the faulting. On the west side of the Lepreau Peninsula (Stop 2) attitudes of strata indicate a major monoclinal fold which trends NNE-SSW within the Triassic Lepreau Formation (Figs. 2, 3, 4). The trend of this structure differs from the trend of pre-Triassic structures, predominantly NE-SW, in the area. The monocline may be related to post-Triassic normal faulting in the underlying metamorphic basement of Carboniferous and older rocks but there is no obvious continuation of the NNE-SSW trending structure either as a fault or a monocline in the older rocks north of the Lepreau Peninsula.

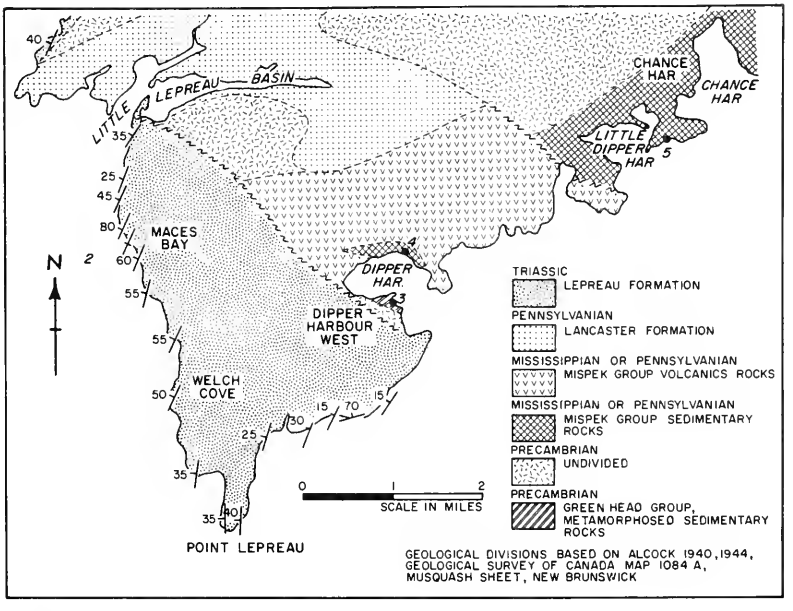


Fig. 2 Geological Map of Lepreau Peninsula.

Pennsylvanian beds of the Lancaster Formation are locally steep (Stop 6) and in places are strongly folded with a penetrative axial plane cleavage inclined moderately to the southeast (Stop 8). The deformation presumably pre-dates the Triassic rocks in which cleavage is absent. The cleavage in the Pennsylvanian is most intense approaching the Variscan 'front' southeast of which Carboniferous and older rocks are intensely deformed by predominantly recumbent structures (Rast and Grant, 1973). The

deformation of the Pennsylvanian rocks is related to the Variscan Orogeny in southern New Brunswick, but lacks the polyphase deformation characteristic of Carboniferous rocks southeast of the 'front'.

Structures produced by two phases of deformation are present in metamorphosed sediments on the north side of Dipper Harbour

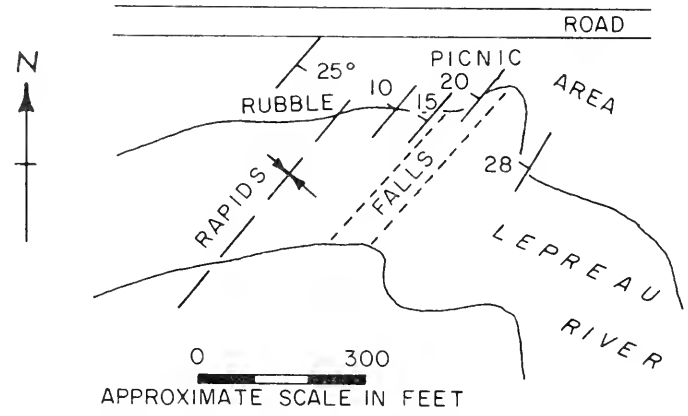


Fig. 3 Sketch map of attitudes of Triassic beds indicating a gentle syncline at Lepreau Falls.

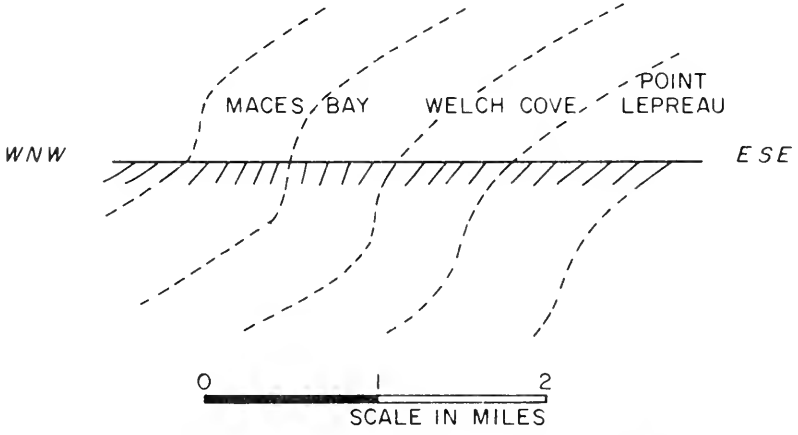


Fig. 4 WNW-ESE section across the west side of Lepreau Peninsula projected from bedding attitudes exposed along the coast indicates a major WNW-facing monocline within the Triassic Lepreau Formation.

(Stop 4) mapped as Carboniferous Mispek Group (Alcock, 1940, 1944). An intense flat-lying schistosity is associated with hinges of recumbent folds of bedding which trend around 055°. The schistosity is deformed by a penetrative crenulation cleavage inclined gently to moderately northwest. The sense of overturning of the schistosity is southeastward. Rocks on the south side of Dipper Harbour (Stop 3), mapped as Precambrian Green Head Group by Alcock, are similar in lithology and structural style to the Carboniferous rocks at Stop 4. Metamorphosed sediments of the Mispek Group with an intense recumbent schistosity deformed by crenulation cleavage inclined gently to moderately northwest are also exposed for a mile north along the coast from Black Point three miles south of Stop 8 on the east side of Saint John Harbour (Fig. 1).

Folds with axial plane schistosity in metamorphosed sediments of the Mispek Group in which the later penetrative crenulation cleavage is lacking are exposed to the east of Little Dipper Harbour (Stop 5). The folds overturn bedding to the northwest and the axial plane cleavage is inclined gently to moderately southeast. The sense of movement of the F_1 folds is not obscured by later structures, and is northwestward.

STOPS 1 to 8 are shown on the geological map, Fig. 1, and STOPS 2 to 5 are shown in more detail on the geological map,

STOP 1 — Lepreau Falls. Triassic Lepreau formation.

Mileage: 84 miles (from Geology Department, University of New Brunswick, Fredericton).

Lithology: purplish red sandstone, parts current bedded, with minor red siltstone.

Structure: beds dip northwest at about 20° in Lepreau Falls. Along the north bank of the Lepreau River westwards from the falls for two hundred feet the dip decreases to about 10° northwest. One hundred feet further west at the top of the bank beds dip southeast at 25°. The changes in dip indicate the hinge of a gentle NE-SW trending syncline of Triassic beds.

Close-spaced (one quarter of an inch) anastomosing joints occur in the red siltstone beds. The joints are sub-vertical and strike NE-SW, simulating an axial plane fracture cleavage.

STOP 2 — Lepreau Peninsula, west side. Triassic Lepreau Formation.

Mileage: 88 miles

Lithology: purplish red sandstone and conglomerate, parts current bedded.

Structure: Along the west side of the Lepreau Peninsula progressive changes in the attitude of bedding indicate a major monocline with NNE-SSW trend within the Triassic Lepreau Formation (Fig. 2 and Fig. 4). At Point Lepreau the dip is about 35°, and the dip increases northwards through 50° at Welch Cove to very steep at Maces Bay, in places vertical. Northwards from the steep zone the WNW dip decreases to about 25°. Several thousand feet of Lepreau Formation are involved.

A half mile traverse from SSE to NNW along the coast at STOP 2 crosses the steep limb of the monocline. The steep beds, predominantly conglomerate, form a prominent feature which extends SSW for two miles out to sea as strike ridges and ledges exposed at low tide.

STOP 3 – Dipper Harbour, south side. Precambrian Green Head Group (?).

Mileage: 92 miles

Lithology: metamorphosed pale grey calcareous siltstones with minor limestone pebble bands.

Structure: Semi-recumbent minor structures formed by two intense phases of deformation are present. A prominent crenulation cleavage produced by the later phase of deformation dips 5° to 20° between west and southwest, and is axial planar to tight minor folds which plunge gently southwards.

The crenulation cleavage and associated minor folds deform a penetrative fine-grained schistosity, overturning it eastwards. The overall attitude of the deformed schistosity is semi-recumbent, dipping southeastwards at about 25°. Limestone pebbles are flattened within the schistosity.

Bedding can be discerned at the north end of the exposure where sub-vertical pebble bands trend 050° across the flat outcrop surfaces.

The rocks are shown as Precambrian Green Head group on the geological map (Alcock, 1940, 1944), but the lithology and polyphase structure can be matched with rocks on the north side of Dipper Harbour (STOP 4) shown as Mississippian or Pennsylvanian Mispek Group on Alcocks map (see also Fig. 2). It is proposed that the rocks at STOP 3 are Carboniferous and that both phases

of deformation are post-Carboniferous. The deformation is considered to be pre-Triassic, since Triassic rocks in the area lack cleavage.

STOP 4 – Dipper Harbour, north side. Mississippian or Pennsylvanian Mispek Group.

Mileage: 93 miles

Lithology: metamorphosed pale grey and purplish calcareous siltstones with limestone pebble bands.

Structure: Two phases of semi-recumbent minor structures similar to those at STOP 3 are present. A flat-lying earlier schistosity is associated with hinge remnants of recumbent folds of bedding which trend around 055° and plunge gently southwestwards. Limestone pebbles are flattened within the schistosity.

A crenulation cleavage which dips between west and northwest at 15° to 35° deforms the schistosity. Where strongly deformed between crenulation cleavage planes, the schistosity is overturned southeastwards.

STOP 5 – Little Dipper Harbour, east side, Mississippian or Pennsylvanian Mispek Group.

Mileage: 98 miles

Lithology: purplish-red sandstone, siltstone, pale grey calcareous siltstone, and thin conglomerate bands including limestone pebbles.

Structure: Varying attitudes of bedding mapped on the tidal platform (Fig. 5) define folds asymmetric to the northwest which plunge gently towards 055°. On the gently inclined limbs bedding dips southeast at 10° to 30°, and in the steep limbs bedding is vertical or slightly overturned, dipping steeply southeast. The folded surface of a bed in the hinge of an anticline is well exposed for over two hundred feet at the west end of the tidal platform.

An axial plane schistosity dipping southeast between 20° and 50° forms a prominent cleavage. Limestone pebbles are flattened within the schistosity.

The rocks may be matched in lithology and structure with those at STOPS 3 and 4, except crenulation appears to be absent.

STOP 6 – West Musquash River. Pennsylvanian Lancaster Formation.

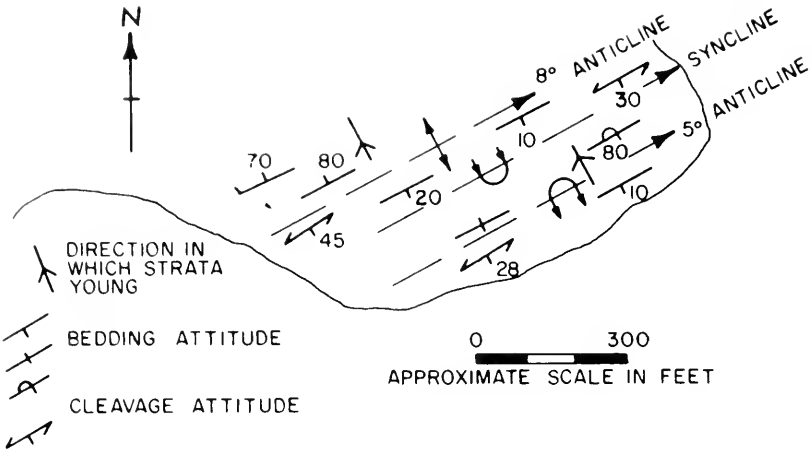


Fig. 5 Sketch map of bedding and cleavage attitudes in folds exposed on the tidal platform on the east side of Little Dipper Harbour.

Mileage: 104 miles

Lithology: thick bedded grey sandstone.

Structure: beds dip south at 50° and strike 095°.

STOP 7 – Musquash Head. Mississippian or Pennsylvanian Mispek Group.

Mileage: 119 miles

Lithology: metamorphosed pale grey siltstone.

Structure: Two phases of deformation are present. Minor folds plunging gently SSE overturn an earlier schistosity westwards. The folded schistosity has an approximate overall dip of about 50° westwards. In places the minor folds have axial plane crenulation cleavage which dips gently southwards.

STOP 8 – Midwood, East Saint John. Pennsylvanian Lancaster Formation.

Lithology: grey and red sandstone and siltstone, with minor conglomerate bands and dark shales. Plant remains are present.

Structure: The hinge of an asymmetric syncline with intense axial plane cleavage is exposed on the tidal platform (Fig. 6). The

fold plunges southwest at 25°, and bedding is overturned towards the northwest. The axial plane cleavage is a fine-grained schistosity which dips southeast between 25° and 45°. Pebbles in conglomerate bands are flattened within the schistosity.

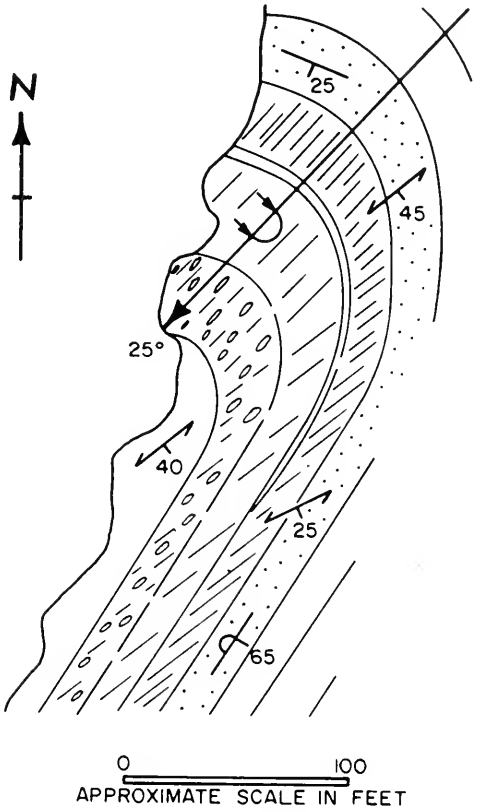
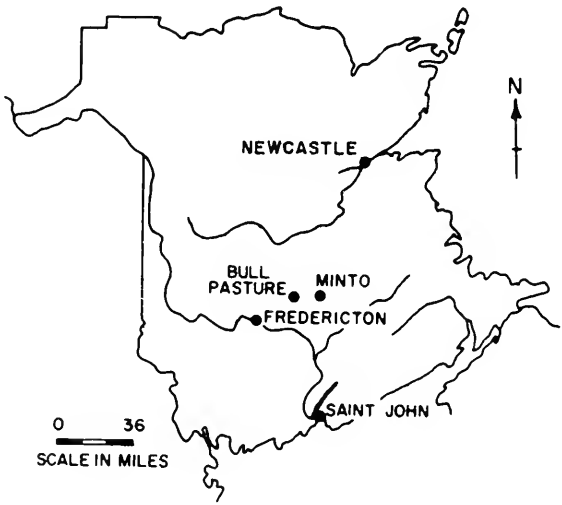


Fig. 6 Diagrammatic plan view of the north end of the tidal platform at Midwood, East Saint John showing the hinge of an asymmetric and plunging syncline with axial plane schistosity in the Pennsylvanian Lancaster Formation.

TRIP A-11, by N. W. Radforth, Muskeg Research Institute, Fredericton, N. B.

MINTO COAL FIELDS

This area is the site of one of the earliest industrial developments in the Province with coal exports to the United States starting over 100 years ago. Geologically, it lies within a large area of eastern New Brunswick composed of red to grey sandstones of Pennsylvanian age. The piles of mine wastes and newly exposed faces in the open pit mines have been a popular "Mecca" for paleobotanists for many years. With a minimum of exploration, a fascinating accumulation of plant fossils can be recovered with only a geologist's hammer. This ease of access enables the amateur naturalist and professional paleobotanist alike to encounter one of the continent's best fossil records of the Carboniferous system.



BULL PASTURE BOG

This muskeg or peatland area is an excellent, undisturbed example of a raised bog. It is typical in that it encompasses all the aspects of raised bog development from minerotrophic to ombrotrophic conditions with an accompanying wide array of plant communities and a wider diversity of species.

Its proximity to the University of New Brunswick and the lack of ecosystem disturbance has enabled researchers at UNB to carry out surveying, development of sampling techniques, palynology, measurement of permeability and thermal conductivity of peat, remote sensing (airborne) techniques of analysis of ground water and vegetation distribution, ground water behaviour and developmental history of muskeg.

The geological significance of this and similar areas is that they provide a fossil record of the recent vegetational climatic and hydrological history of the region.

Easily identified as organic terrain, it is particularly impressive when viewed from the air, when it becomes obvious as a dynamic, developing feature of the New Brunswick landscape.

LOG AND DIRECTIONS

Location of Field Study:

– near Minto at the site of New Brunswick Coal Strip Mine and Bull Pasture in the Acadian Forest Reserve.

SITE 1 – ROUTE:

9:00 – leave Fredericton (Route 10) Geology Bldg. to near Minto – see N. B. Road map – about 25 miles.

10:00 – arrive Minto Coalfield (site of strip mine)

12:00 to
1:00 – Lunch (box lunch)

SITE 2 – ROUTE:

14:00 – leave strip mines for Bull Pasture (see airphoto) via Route 10 towards Fredericton taking access forest trail (no. 10) to Bull Pasture (topo map)

15:30 – leave for Fredericton

16:30 – arrive Fredericton

Objectives, Site 1 – to hear short account of Minto Coal Flora and geology of Minto Basin

– to engage in fossil hunt

Objectives, Site 2 – to hear story of the Bull Pasture Bog, study muskeg type, hydrology and survey procedure

REQUIREMENTS:

- Knee waders, geologist's hammer, box lunch, 4 old newspapers, 1 1/2" nails
- For those keeping fossil compressions (the best in N. America), boxes will be provided and shipping charges levied.
- packing of fossils (by delegates at strip mine)

FIELD TEAM:

- courtesy Muskeg Research Institute, U.N.B.

In event of rain:

- lunch in buses and no shipment of fossils

TRIP A-12, by I. S. Parrish and J. V. Tully, Brunswick Tin Mines Ltd.

MOLYBDENUM, TUNGSTEN AND BISMUTH MINERALIZATION AT BRUNSWICK TIN MINES LTD.

The exploration of the Mount Pleasant property of Brunswick Tin Mines Ltd., is being carried out by the exploration division of the Sullivan Mining Group. The exploration program has outlined a very large block of mineralized ground containing in excess of thirty million tons and grading about 0.1% molybdenum, 0.2% tungsten and 0.08% bismuth.

INTRODUCTION

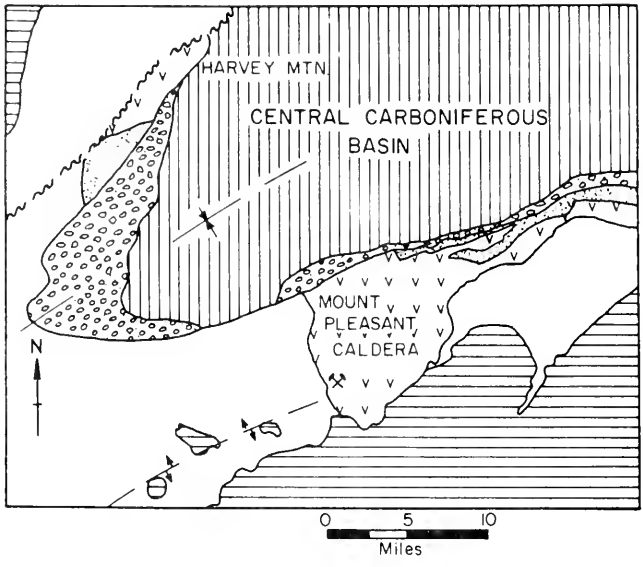
LOCATION – Brunswick Tin Mines is located in north central Charlotte County of southwestern New Brunswick (Fig. 1). The property can be reached by road from either St. George or St. Stephen, a distance of about thirty-five miles.

TOPOGRAPHY – The most prominent topographic feature in the area is Mount Pleasant, a slightly arcuate northwest trending ridge that reaches a height of 1,175 feet above sea level or some 750 feet above the nearby valley floors. Over-burden ranges up to several tens of feet and averages about ten feet in thickness. Rock exposures are sparse excepting along streams and steep hillsides and where earlier prospecting has uncovered the bedrock.

HISTORY – In March, 1967 the Sullivan Mining Group obtained an option on the property through an agreement between Sullico Mines Ltd., Mount Pleasant Mines Ltd., and St. George Molybdenite Mines Ltd. Additional geophysics was carried out and diamond drilling began again. The option was exercised and in mid-1969 Brunswick Tin Mines was formed to further explore and develop the property.

DEVELOPMENT – To January 1, 1971 there has been a total of 211,253 feet of diamond drilling done at Mount Pleasant. Of the 121,570 feet drilled by the Sullivan Mining Group, 113,402 feet was from surface.

There are three adits on the property (Fig. 2). The 600 was driven by Mount Pleasant Mines Ltd. It is located at the north end of Mount Pleasant. There are 4,808 feet of lateral advance and 538 feet of raise in this adit. The two adits driven by Bruns-



PENNSYLVANIAN

Grey sandstone, conglomerate and red siltstone

MISSISSIPPIAN and/or PENNSYLVANIAN

Red conglomerate and arkosic sandstone

MISSISSIPPIAN

Red conglomerate and arkosic sandstone, minor red and green siltstone

Silicic volcanic flows, tuffs, ash flow tuffs and related intrusive rocks

DEVONIAN (MAINLY)

Mainly granite, quartz monzonite and granodiorite

PRE-DEVONIAN

Folded Ordovician and Silurian greywacke, slate

Fig. 1 General geology of a portion of Southwestern New Brunswick showing the distribution of Carboniferous volcanic rocks.

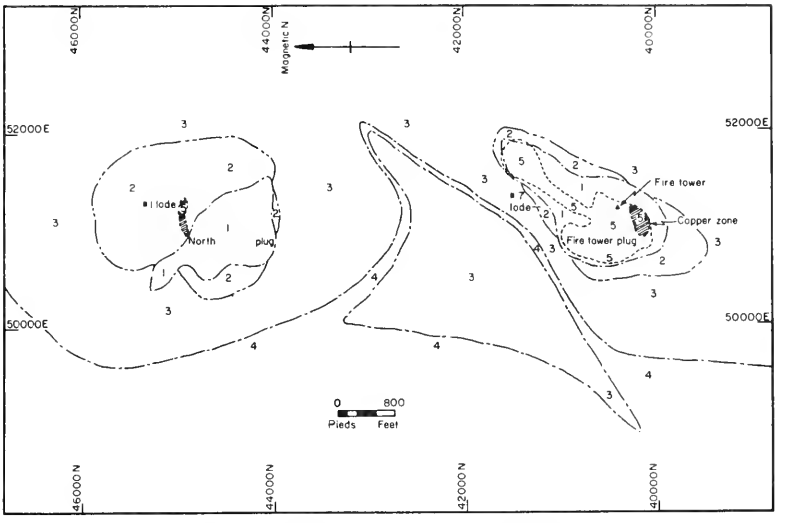


Fig. 2 Generalized geological plan, Mt. Pleasant area showing location of vent deposits and related rocks 1 - latite porphyry breccia; 2 - intrusive rhyolite, 3 - rhyolite flow; 4 - metasediments; 5 - Ordovician argillite; 6 - mineralized zone (after Parrish and Tully, 1971)

wick Tin Mines are over one mile south of the 600 workings. The main Brunswick Tin adit was driven at 750 elevation. Total underground advance on the 750 level is 4,375 feet. In addition 154 feet of raise and 100 feet of subdrift were driven off this level. The second Brunswick Tin adit was collared north and east of the 750 adit and at 900 feet in elevation. Total advance in this adit is 638 feet.

GEOLOGY

REGIONAL GEOLOGY — Mount Pleasant is on the western margin of a volcanic basin and also on the axis and near the eastern nose of a large anticlinal structure known as St. David's Dome (Fig. 2). This northeasterly trending structure either plunges down to the northeast under the basin or dies out at the basin's edge.

The property is bounded by four major rock units. To the east the basin is composed of volcanic quartz feldspar porphyries of Mississippian age and a very similar intrusive unit. These two units have been later intruded by a fine-grained acid rock that has been locally called tuffite.

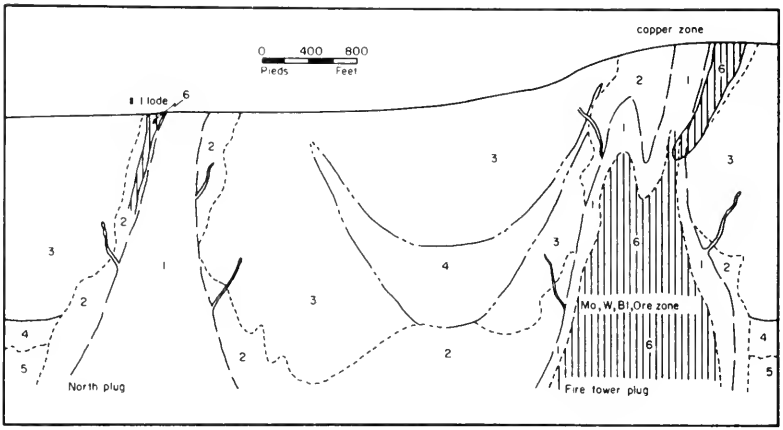


Fig. 3 Cross section through vent zones at Mt. Pleasant. 1 - latite porphyry breccia; 2 - intrusive rhyolite; 3 - rhyolite flow; 4 - Ordovician argillite; 5 - mineralized zone; 6 - copper zone (Parrish and Tully).

The northern side of the basin lies against the southeastern edge of a major Pennsylvanian sedimentary basin. The southern side of the volcanic basin lies against a batholith of Devonian granite. To the west of the basin is a series of slightly metamorphosed Silurian-Devonian argillites and greywackes intruded by a series of igneous rocks that range from gabbro-diorite at St. Stephen to granitic plugs near Mount Pleasant.

LOCAL GEOLOGY – Structurally, Mount Pleasant is composed of two nearly vertical acid intrusive plugs and an intervening saddle of metasedimentary and volcanic rocks (Figs. 2 and 3).

The area originally consisted of Lower Paleozoic sediments over which a series of Mississippian volcanics were extruded. There was then a period of upwarping accompanied by intrusion of the feldspar porphyries. As upwarp continued, two plugs of highly gaseous acidic magma were intruded into the earlier intrusive porphyry and in places into the volcanic porphyries. The intrusion was probably violent, as is evidenced by the numerous brecciated contacts. There were likely several periods of intrusion as evidenced by acid dykes cutting earlier acid intrusions. Cross-cutting breccia dykes are also present. The banding in underground exposures is parallel to the major fracture patterns and is due to successive stages of alteration which have migrated outwards from the fractures. Intrusion of the plugs has also resulted in a downwarping of the Silurian-

Devonian metasediments and earlier volcanics. These units are present in the saddle between the North and Fire Tower Plugs.

All the rocks within the property are fine-grained and with the exception of the metasedimentary units, have been highly altered. Thus in intensely altered zones where original textures have been obliterated, classification is very difficult.

The rock classification at Mount Pleasant is based primarily on discernable map units rather than on conventional classification systems.

ROCK TYPES

Argillites — Silurian-Devonian argillites, which are the oldest rocks on the property, are chocolate brown in color, fine grained, and poorly banded. Mineralization is sparse.

Quartz Feldspar Porphyries — There appear to be two types of porphyritic rock on the property: a volcanic and an intrusive variety. Both are thought to be Mississippian in age.

The volcanic variety is generally pale to dark green, chloritic, and contains up to 20% buff to pink feldspars and 5% to 10% vitreous quartz eyes, in a fine-grained siliceous matrix. Some sections exhibit faint suggestions of flow tops and flow structures and others contain angular chloritized fragments.

Mineralization is sporadic and consists of small pods and disseminations of chalcopyrite, sphalerite, galena, and molybdenite. Mineralization is most uniform and constant near the contacts with either of the intrusive rocks.

The intrusive variety is distinguished from the preceding by the amount and nature of the quartz eyes. The intrusive porphyry contains up to 2% of quartz eyes but they are the dull grey, milky type. The matrix of the intrusive unit is slightly coarser than that of the volcanic and has a sugary texture. Flow features and fragments are lacking. The contacts with both the argillite and the acid plugs are well-brecciated. The nature of the contact with the volcanic porphyry is poorly known.

Alteration within this unit is much more intense than in the volcanic porphyry. In general, the feldspars are grey to buff and exhibit varying degree of saussuritization and kaolinization. In many cases the feldspar and quartz phenocrysts have been completely obliterated by intense silicification.

Mineralization is more widespread than in the volcanic por-

phyry. The Copper Zone and the other copper - tin - zinc deposits are found predominantly in the intrusive unit.

Acid Intrusive — The acid intrusive is buff-tan to flesh pink in color and consists almost entirely of quartz and feldspar. Its matrix is slightly coarser grained than either of the porphyries and is generally brecciated throughout. Old property records refer to this rock as "tuffite".

The tuffite exhibits a strongly brecciated contact with the intrusive porphyry and many tuffite dykes cut both types of porphyries. Numerous siliceous dykes cut the tuffite. They include dense grey siliceous dykes, quartz pebble dykes, breccia dykes, and massive chloritic tuffite dykes which are completely irregular in their trends and often crosscut one another. These dykes plus the brecciated nature of the tuffite suggest that the tuffite plugs were drilled through the enclosing rocks by the explosive energy of a gas charged magma.

Alteration is most intense within the tuffite and consists of silicification, kaolinization, fluoritization and potassic alteration. The tuffite is the host rock for the molybdenum, tungsten and bismuth type mineralization.

Alteration — Seven principal types of alteration have been noted: silicic, chloritic, hematitic, fluoritic, kaolinitic, potassic and sericitic. The types are telescoped and there is considerable overlapping and omissions. A broad zoning of alteration as related to the potential orebodies is discernable (Figs. 4 and 5).

Chloritic alteration is most pronounced in barren areas removed from the mineralization. As one nears the mineralization there is a narrow irregular zone of hematitic alteration. Iron oxidation is uncommon in the mineralized area. Inside of the hematitic band is a broad band of kaolinization. This extends into the upper and outer parts of the body. Overlapping the kaolinization is a broader area of fluoritization.

The fluorite is closely associated with the mineralized zones at all elevations but is much more widespread than the ore mineralization. Topaz is locally abundant within the zones. Potassic alteration is very closely related to favorable host rocks and is seldom present where ore values are absent. Potassic alteration refers to a pinkish coloration, the exact chemical nature of which has not as yet been established. The alteration and color is similar to that of potassic alteration found in other areas. Sericitization is widespread. Its distribution is not completely understood, but it may form a very broad envelope about the

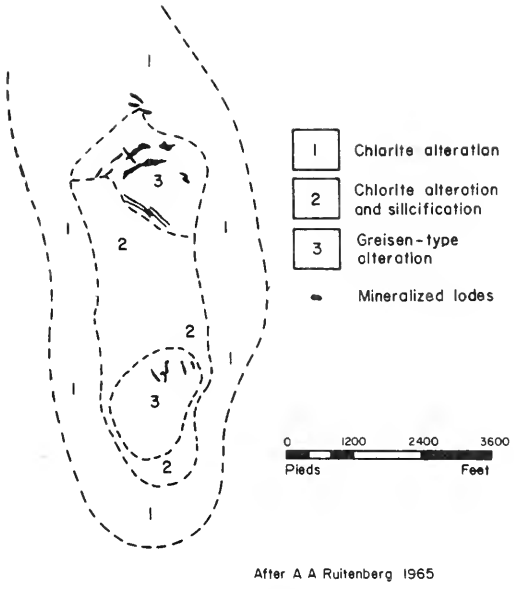


Fig. 4 Surface map showing the general distribution of alteration halos around volcanic vents at Mt. Pleasant.

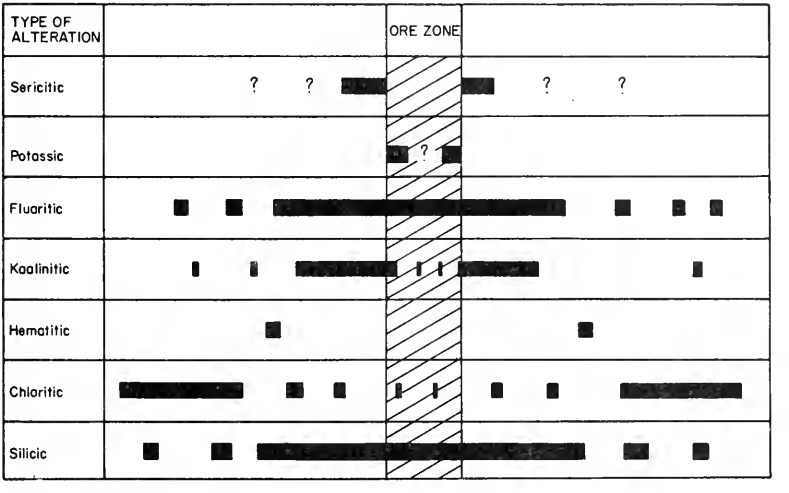


Fig. 5 Diagrammatic representation of alteration zones around the Bi-W-Sn-Mo Zone, Mt. Pleasant (Parrish and Tully, 1971)

mineralized bodies. The pervasive silicification is of little use as a guide to mineralization as it is everywhere present at Mount Pleasant. Regionally it can be an effective indicator of areas worthy of closer prospecting.

At Mount Pleasant, alteration is most intense and varied in the porphyries at or adjacent to the contact of the porphyries with the tuffite.

Mineralization — Two types of potential orebodies are present at Mount Pleasant. These are the molybdenum - tungsten - bismuth type and the copper - tin - zinc type. There are four important differences between the two types of orebodies. These are in ore control, mineralogy, size and host rocks.

Copper - tin - zinc deposits are closely controlled by the porphyry-tuffite contact, commonly occurring where there is an abrupt change in its strike. Within the ore zone mineralization is most often found at the intersection of cross fractures. No such obvious control exists for the molybdenum - tungsten - bismuth deposits. These deposits appear to be confined to highly siliceous fractured and brecciated zones within the intrusive tuffite. Mineralization however is not confined to fractures or to intersections of fractures and may occur as either disseminations or as fracture coatings or fillings.

Molybdenum - tungsten - bismuth deposits consist primarily of molybdenite, wolframite, bismuthinite, native bismuth, arsenopyrite, sphalerite, and fluorite in a quartz-feldspar matrix. Copper - tin - zinc deposits contain tin, copper, lead, zinc and silver as well as minor amounts of molybdenum, arsenic, tungsten, bismuth, indium, gallium and cadmium. The mineralogy is described in detail by Petruk (1964).

Molybdenum - tungsten - bismuth deposits measure hundreds of feet in all directions. They contain millions of tons of potential ore. Known copper - tin - zinc deposits are more restricted in each dimension.

Lastly molybdenum - tungsten - bismuth deposits occur principally in tuffite, whereas copper - tin - zinc deposits occur principally in porphyry at or near the contact of the porphyry with the tuffite.

Copper - Tin - Zinc Deposits — Several deposits of copper - tin - zinc are known in the Mount Pleasant area. At this time only three appear to be of economic significance. These are known as the # 1 and associated lodes, the # 7 lode and the Copper Zone. (Fig. 3).

The # 1 and associated lodes are a vein swarm. The swarm is located at the north end of the North Tuffite Plug, within the silicified porphyritic intrusive and in brecciated zones near the contact with the tuffite. The host rock is intensely kaolinized and in places is heavily fluoritized. The mineralized zone is a few tens of feet wide and three hundred feet long. It apparently extends only a few hundred feet in depth. Within this body are numerous veins, veinlets, lenses and pockets of sphalerite, galena and fluorite, with varying amounts of cassiterite and chalcopyrite.

The # 7 lode was developed by the Sullivan Mining Group at 900 elevation. It lies on the north contact of the Fire Tower Plug. The # 7 lode is 100 feet long and ten feet wide. It occurs within and adjacent to a breccia dyke extending north-south which is at right angles to the tuffite-porphyry contact. The mineralization consists of sphalerite, galena, cassiterite, stannite and chalcopyrite. The sulfides form the cement for the tuffite-breccia dyke, and also occur as disseminations in the enclosing porphyry. Depth potential is limited as the breccia dyke pinches out above the 750 level. There is very little alteration associated with the # 7 lode. The # 7 lode is estimated to contain 250,000 tons averaging 1.2% Cu, 0.7% Sn, 4.5% Zn, 0.7 oz. Ag.

The third potentially economic copper - tin - zinc deposit is the Copper Zone. This zone is located at the south end of the Fire Tower Plug. It is entirely within the porphyritic quartz feldspar intrusive. The principal ore values occur as disseminated chalcopyrite blebs, augmented by randomly located high grade chloritic pockets of sphalerite - chalcopyrite - fluorite mineralization. Alteration is as disseminated green chlorite laths and moderate silicification. The body is ovate and about 600 feet high and up to 200 feet in diameter and contains approximately two million tons. With depth the Copper Zone merges into the upper part of the main molybdenum - tungsten - bismuth ore body.

Molybdenum - Tungsten - Bismuth Deposits — By far the most significant mineralization consists of molybdenum - tungsten and bismuth disseminated in a broad zone within the tuffite in the Fire Tower Plug. The irregular ore zone trends roughly north and is parallel to the porphyry-tuffite contact (Fig. 2). Widths range from more than 700 feet in the southern end to less than 200 feet in the northern end. Total strike length is more than 1500 feet.

The ore zone has been outlined to a depth of 200 feet below sea level. The potential ore from 200 feet below sea level to 900

feet above sea level is more than 30 million tons and has an estimated grade of 0.1% Mo, 0.2% W, and 0.08% Bi.

Table 1 illustrates the width and tenor of the orebody as intersected by diamond drilling:

TABLE 1

Ore Values and Intersection Lengths of Drill Holes

DDH MPS #	LENGTH	Mo %	W %	Bi %
66	491'	.106	.166	.056
90	610'	.127	.177	.091
97	674'	.109	.276	.167
105	345'	.118	.198	.042
119	430'	.053	.178	.069

Within the ore zone, kaolinization is widespread but appears to be more prevalent and concentrated in the upper portions of the orebody. Fluoritization, which is widespread in the upper portion, is less prominent at depth. Chlorite, which forms on the outside margins of the ore zones, dies out with depth.

The dominant ore elements are molybdenum, tungsten and bismuth. Copper, tin, zinc and lead are present in the upper portions of the orebody but are found in only minor amounts with depth. There is a pronounced vertical zoning for molybdenum, tungsten and bismuth. Table 2 lists the estimated grades per 100 foot elevation. The table illustrates that molybdenum, tungsten and bismuth all increase in concentration to 200 feet above sea level. The concentration of bismuth rapidly decreases below this point. The peak concentrations of molybdenum and tungsten are at sea level. Below sea level, tungsten values decrease more rapidly than do molybdenum values.

TABLE 2

Calculated Grades for Southern End of the Orebody

ELEVATION	Mo %	W %	Bi %
+ 400	.039	.131	.071
+ 300	.055	.172	.079
+ 200	.085	.208	.095
+ 100	.104	.211	.085
Sea Level	.154	.219	.075
− 100	.129	.162	.055
− 200	.133	.148	.031

The distribution of the ore values within the ore zone is such that at both ends of the body there is a sharp decrease in values, going from the tuffite into the porphyry. Since no sharp rock contact or major structure controls the width of the zone, assay values are erratic on the sides of the deposit. The four main ore minerals are molybdenite, wolframite-ferberite, native bismuth and bismuthinite.

Molybdenite occurs in flakes and books in quartz veinlets and as fracture coatings, the average grain size being 50-100 microns. The only other molybdenum mineral is ferrimolybdite which occurs near surface on fractures.

Tungsten occurs as wolframite in fine disseminated grains. Petruk (1964) states that the wolframite is mostly of the iron-rich ferberite variety. Scheelite although present is very rare.

Bismuth occurs as native bismuth and as bismuthinite. Both occur as grains and aggregates in either silicified or chloritized rock. Much bismuth is present as inclusions in arsenopyrite.

Recent exploration drilling in the North Tuffite Plug (Fig. 2) has found molybdenum, tungsten and bismuth mineralization similar to that in the Fire Tower Plug. Holes to date have explored the zone to a shallow depth only. This is very similar to what drill holes in the upper portions of the Fire Tower Plug intersected.

ACKNOWLEDGMENTS

The foregoing report summarizes our findings to date. We would be remiss if we did not acknowledge the aid given us by Messrs. Gilles Carrière, Pierre Sauvé and Jose Nunes of the Exploration Division of the Sullivan Mining Group. We would also like to express our appreciation to the executive of the Sullivan Mining Group, Messrs. J. J. Beauchemin, A. Beauchemin and L. C. Béliveau for their permission to publish this paper.

LOG AND DIRECTIONS

MILEAGE

0.0 Junction of Highway 1 and 3. Turn right onto Highway 1.

5.8 Turn left onto Highway 760

7.0 Continue straight through this junction (instead of turning right).

11.3 Turn right

11.9 Turn left onto Highway 765

12.2 Turn right onto Highway 770

14.7 Straight ahead following the sign to Pleasant Ridge.

15.0 Covered bridge over the Digdeguash River.

18.9 Turn left onto the continuation of Highway 770.

22.6 Turn right (staying on Highway 770); end of pavement for the remainder of the way into Mount Pleasant.

24.4 Turn right, continuing on Highway 770; roads will deteriorate. We're now travelling along a stagecoach route of the late 1700's and early 1800's.

26.9 Descend hill to Magaguadavic River (we lose Highway 770 to the right).

27.3 Bridge over the Magaguadavic River.

27.6 Depending on road conditions at time of trip we will either turn left (new pulp and paper company road) or continue straight. It is likely that the pulp road to the left will be the better at the time of the trip. Bracketed mileages refer to the straight through road. Both roads meet again at the covered bridge over the Piskahegan River. On the left road, make a right turn at every junction (3 times) over a distance of 3.3 miles.

30.9 Covered bridge over the Piskahegan River (29.8).

31.6 Turn right at Mt. Pleasant Tin Mines sign (30.5).

32.6 Gate to Brunswick Tin Mines Property (31.5).

The underground workings should be reasonably dry though cool and therefore normal field boots and clothing appropriate for the time of year will suffice. There will be no climbing of raises, etc. Lights and hard hats will be provided if possible. For your own convenience those having underground equipment (hard hats, lamps including flash lights, hand held lanterns etc. and belts) are advised to bring same. The locations of Stops 1 through 4 are shown on Fig. 6 and the remainder on Fig. 7.

STOP DESCRIPTIONS

STOP 1 — Brecciated sedimentary rocks of the Waweig Formation. (Late Silurian-Early Devonian), in part intruded by silicic volcanic rocks of the Mount Pleasant Complex.

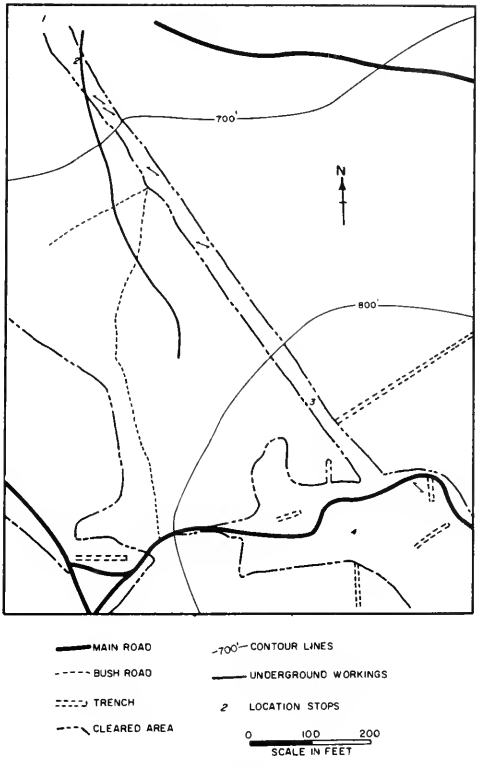


Fig. 6

STOP 2 — Contact between sedimentary rocks of the Waweig Formation and the earliest altered feldspar-quartz porphyry (Early Carboniferous). It is believed to be the altered equivalent of the Rothea ash-flow tuff, east of Mount Pleasant. Here Dr. Mousseau Tremblay made the first discovery of tin minerals.

STOP 3 — Contact zone of altered feldspar-quartz porphyry and feldspar porphyry (latite).

STOP 4 — Altered feldspar-porphyry intruded by dark green, chloritized and fawn colored, silicified tuffite dykes. The dykes are roughly parallel with the main tuffite-feldspar porphyry contact in this area.

A mineralized fracture zone with tin minerals, base metal sulfides, fluorite and kaolin is partly exposed.

STOP 5 — Tuffites and breccias are well exposed and they are

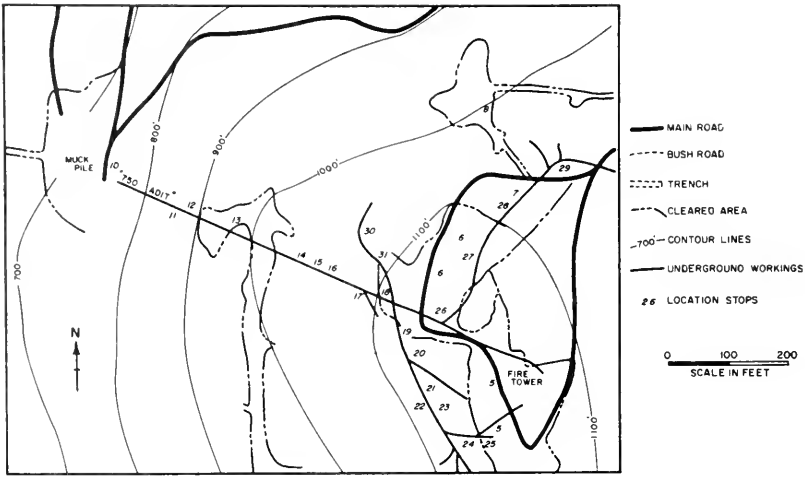


Fig. 7

believed to occupy a volcanic neck similar to those in the vicinity of Stop 4. Silicified tuffite shows locally orbicular banding. They could be Liesegang rings produced by rock alteration.

STOP 6 — Cleared area above western ore body of Main Fire Tower Mo-W-Bi zone. Both dark green, chloritized and fawn brown to flesh colored silicified tuffites are exposed, similar to those at Stops 4 and 5. A later stage of coarser tuffite dykes and two groups of breccia intrude the earlier tuffite. Some arsenopyrite, fluorite and molybdate may be seen especially near the northern edge of the clearing.

STOP 7 — Rock cut directly above 750 adit slash. Fluorite and molybdenite may be seen here in highly brecciated and silicified porphyry intruded by tuffite.

STOP 8 — Main contact of the most southern tuffite intrusion with porphyry. An irregular breccia pipe rich in base metal sulfides and tin minerals is partly exposed along this contact.

STOP 9 — Dump at 900 adit. Sphalerite, galena, chalcopyrite, cassiterite and stannite, occur in porphyry and tuffite. Galena is tarnished due to presence of indium. Roquesite has been identified in polished sections from samples of this area.

STOP 10 — The 750 adit is 1200 feet down the road from Stop 9. Please wait for your guides.

STOP 11 — Argillite band incorporated into volcanic porphyry.

STOP 12 — Angular fragments of pink tuffite occur sporadically through the volcanic porphyry.

STOP 13 — Hematite staining of rock as a halo about the ore body.

STOP 14 — A small breccia dike or pipe with much kaolin and minor sulfides. This is a miniature of the type of structures found in the 600 adit.

STOP 15 — Sharp walled breccia dike.

STOP 16 — Block of silicified tuffite.

STOP 17 — Silicified porphyry. The short drift to the south shows excellent fluorescent and phosphorescent fluorite and sphalerite(?). Note the molybdenite covered slip face at the entrance to the drift.

STOP 18 — The contact of the porphyry with the tuffite is drawn along the tuffite breccia at this point.

STOP 19 — Grey dike. One of the many types of cross-cutting rocks through the tuffite. Note the breccia that appears to have settled in the fine grey dust-like matrix.

STOP 20 — Typical ore structures. The left wall assays .03 Mo, .12 W, .03 Bi, 1.50 As for 50 feet from drift portal.

STOP 21 — The south contact of the tuffite with the porphyry is well exposed on the east wall of the drift.

STOP 22 — A very flat-dipping breccia pod can be seen in both walls.

STOP 23 — Tetrahedrite crystals in the back of the drift and "honey" sphalerite on the left wall.

STOP 24 — Typical exposure of the porphyry copper zone.

STOP 25 — A chlorite filled "blow-hole" or mineralized fumarole.

STOP 26 — Orbicular tuffite. The banding may be solely an alteration feature.

STOP 27 — Contact between green, barren tuffite and low grade silicified tuffite.

STOP 28 — The walls here have been slashed to provide muck for metallurgical testing.

STOP 29 — A quartz vein or quartz pod associated with minor faulting and tin mineralization. Note the abundant fluorite.

STOP 30 — Tuffite dike. A late stage of tuffite, very rarely mineralized.

STOP 31 — Breccia dike near Porphyry Tuffite contact.

TRIP A-13 and B-10, by I. M. Patel, The University of New Brunswick in Saint John.

SAINT JOHN AREA

INTRODUCTION

Geographically the city of Saint John and its outlying suburbs are a part of the Southern New Brunswick belt characterised by the northeast — southwest structural trend and involving rocks varying in age from Precambrian to Carboniferous. The succession is shown in Fig. 1. The object of this excursion is to illustrate the stratigraphic sequence and its deformation as well as the associated intrusive activity.

STRATIGRAPHY

The earliest sedimentary rocks in the St. John area are a group of metalimestones, impure sandy phyllites and quartzites, collectively known as the Green Head Group (Hayes and Howell, 1937). The group has been investigated by Leavitt (1963) and mapped out to the west and north-west of the city by Leavitt and Hamilton (1962). The carbonates of the group vary from blue-gray calcite marbles to yellowish and white dolomites and in places there are interbedded conglomerates. On Green Head islands the stromatolite Archeozoon acadiense (Matthew, 1890) has been recognised.

The rocks of the Green Head Group are overlain possibly unconformably by volcanics of the Coldbrook Group (Hayes and Howell). These have been recently dated by K-Ar isotope methods to yield an age of 750 ± 80 m.y. (Cormier, 1969). The contact between this group and the presumably older and more highly metamorphosed Green Head Group is everywhere faulted or affected by tectonic sliding. The volcanics consist of sub-acid, dacitic and rhyodacitic ash-flow and ash-fall tuffs, in parts andesites. The presence of well-developed ash-flow tuffs without any bedding suggests a sub-aerial origin for these rocks. In the city these rocks have been severely faulted (Fig. 1) and only a small thickness of them separates the Green Head Group from the Cambrian.

The Cambrian of the City of St. John presents an appreciable interest. The succession, although usually tectonically attenuated and strongly folded is nevertheless fairly complete. It starts with Lower Cambrian conglomerates, red beds, shales and quartzites which from exposures to be seen at various localities northeast of

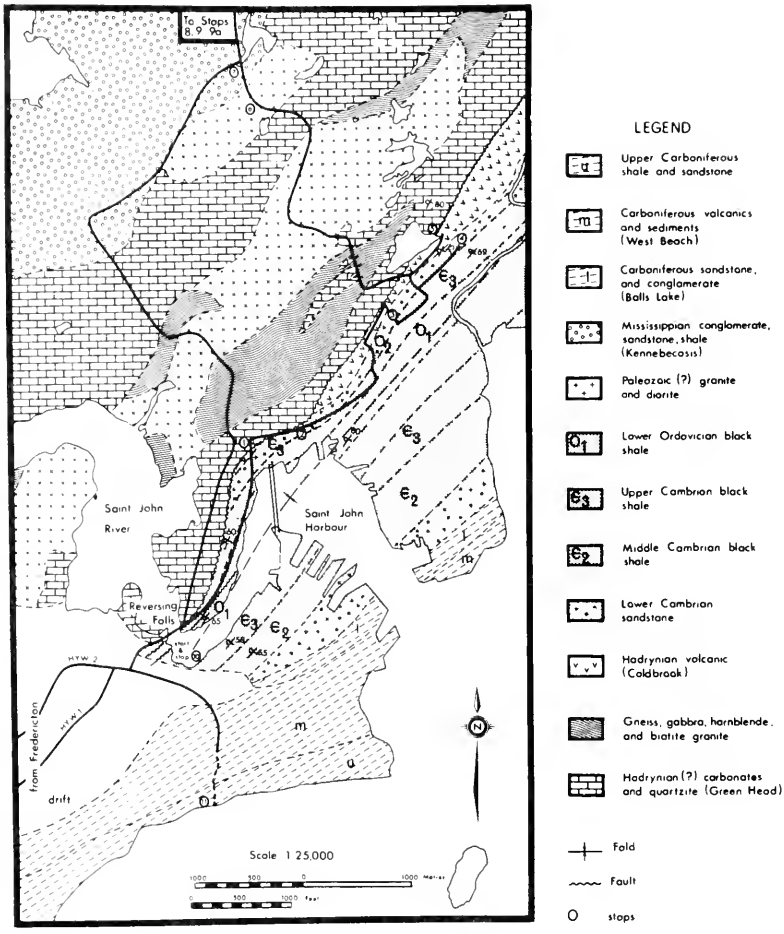


Fig. 1 Geology of Saint John from Hayes and Howell (1937) and Alcock (1938).

St. John could be demonstrated to have been derived from the northwest. Overlying these rocks are marine sediments (330 m.) of late Lower Cambrian to Lower Ordovician. These sediments consist of dark grey and black shales with subsidiary sandstones and limestones. In the City of St. John only very thin remnants of these rocks are present.

The Ordovician black shales are well exposed and in places

yielded Tremadoc and Arching graptolites. No Middle or Upper Ordovician or Silurian rocks have been found in the area.

In the northern part of the city the Precambrian and Lower Palaeozoic rocks are unconformably covered by the Lower Carboniferous Kennebecasis Formation of conglomerates and coarse sandstones usually showing signs of proximal derivation. In the south of the City the Carboniferous succession involving Lower and Upper Carboniferous formations, often in a strongly deformed state is in a fault contact with the Cambrian. Here, Lower Carboniferous rocks show signs of vulcanicity including well developed pillow lavas.

STRUCTURE

Under the Carboniferous cover the Precambrian and Lower Palaeozoic rocks are folded into a major anticline and the adjacent syncline. The syncline has been recently mapped by Richards (1971), who proposes that Precambrian and Lower Palaeozoic formations have been affected by two phases of Middle Devonian, Acadian Orogeny involving refolding and multiple cleavage. Recent work in southern St. John brings to light considerable overthrusting and deformation of Carboniferous rocks, which are in places overturned and face into the Cambrian.

LOG AND DIRECTIONS

Start from Reversing Falls Parking Lot.

Miles from
Last Stop

1.3 STOP 1 — Harrison St. Early & Late Precambrian carbonates & volcanics overlain by upper Lower and Middle Cambrian sediments.

0.5 STOP 2 — Main St. Base of Lower Paleozoic marine sequence, resting on volcanics, faulted against low-grade metamorphics.

1.2 STOP 3 — Goodrich St. Cambrian red beds, quartzite, slate and shales. Fossil locality.

0.5 STOP 4 — Highwood Drive. Basal Cambrian conglomerate resting on Precambrian volcanics.

0.5 STOP 5 — Rockwood Park. Slide contact between early Precambrian carbonates and late Precambrian volcanics.

2.3 STOP 6 — Sandy Point Road. Devonian diorite intrusives.

0.2 STOP 7 – Sandy Point Road & University Ave. Lower Carboniferous conglomerate and sandstone.

4.1 STOP 8 – New HWY. (north). Precambrian biotite gneiss and carbonates.

0.9 STOP 9 – New HWY. (south). Precambrian quartzites.

0.2 STOP 9A – New HWY. (south). Precambrian volcanics (ignimbrites)

7.6 STOP 10 – Reversing Falls. Lower Ordovician slate faulted against Precambrian carbonates.

1.4 STOP 11 – Duck Cove at Seaside Park. Upper Carboniferous "Fern Ledges". Plant fossil locality.

TRIP A-14 and B-11, by G. E. Pajari, University of New Brunswick.

THE HARVEY VOLCANIC AREA

INTRODUCTION

The Harvey Formation forms a distinctive unit along the northwestern margin of the extensive Carboniferous basin (Freeze, 1936; Laughlin, 1960; Kuan, 1970). The Harvey Formation is underlain by Mississippian red siltstones and conglomerates. The volcanic rocks are rhyolites (*sensu stricto*) in composition, plotting in and near the minima field of Petrogeny's Residua system, and are of similar composition in both members of the Harvey Formation. Flow folds in flow-layered lavas indicate a southerly source for the volcanic rocks. The Mississippian rocks unconformably overlie the Silurian strata and are overlain by the Mississippian and/or Pennsylvanian conglomerates and sandstones (Fig. 1).

The Harvey Formation has a regional dip of 10-20° southward toward the axis of the Carboniferous basin. The stratigraphic sequence is as follows:

CARBONIFEROUS	Mississippian and/or Pennsylvanian		Conglomerate, sandstone, siltstone and shale
	Mississippian Harvey Formation	Harvey Mountain Member	Lava flow Ash-fall tuff Agglomerate
		York Mills Member	Ash-flow tuff volcanogenic sedimentary rocks & conglomerate and tuff.

Stratigraphic and petrologic data suggests that the Harvey Formation is correlative with the volcanic rocks of the Piskahegan Group at Mt. Pleasant along the southern edge of the basin — a distance of 15 miles (van de Poll, 1967; Kuan, 1970).

LOG AND STOP DESCRIPTIONS

MILEAGE

0.0 Parking lot beside Geology Department, U.N.B. Proceed west along Highway # 2 (Trans-Canada Highway).

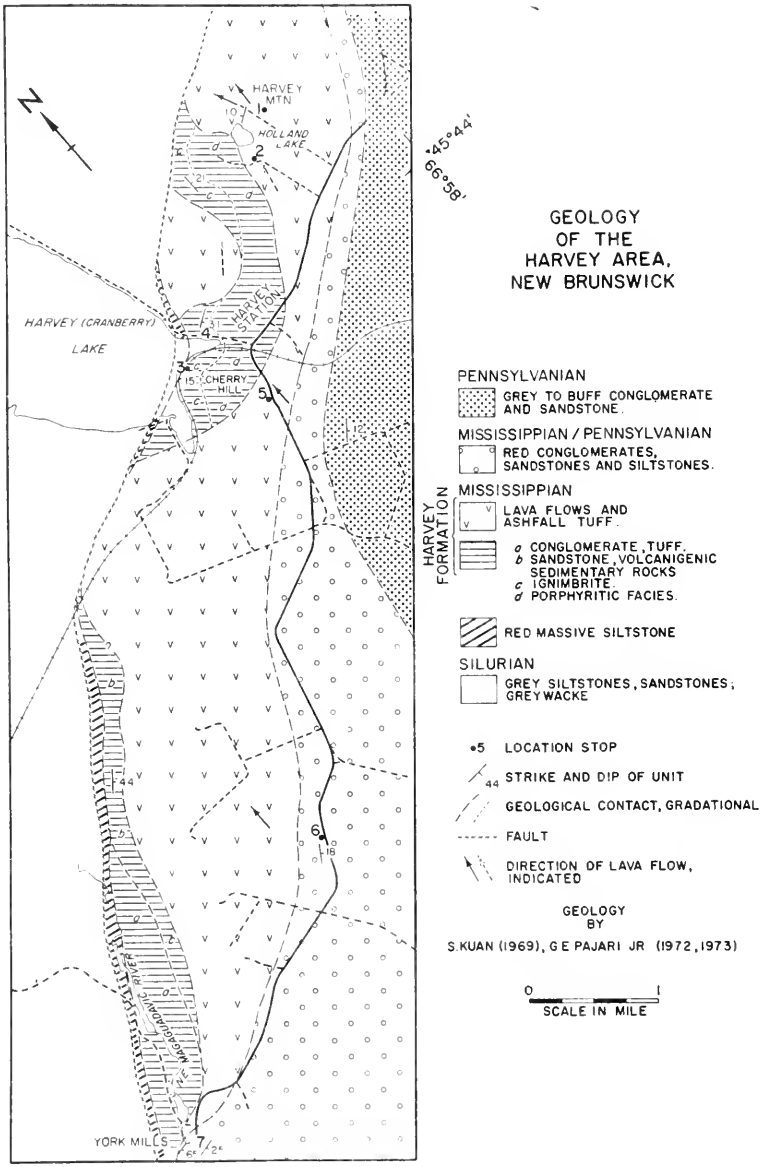


Fig. 1 Geology of the Harvey Area, N. B.

9.0 On the right, the Mactaquac Hydroelectric Power Station.

14.0 Turn right on Highway # 3 and proceed toward Harvey.

28.0 Turn right along the fire-tower access road and proceed to tower. Follow trail westward (a distance of 250 yards) to the edge of the cliff overlooking Holland Lake.

STOP 1 The field immediately to the west of Holland Lake is underlain by a porphyritic facies of an ash-flow tuff that will be seen at Stops 3 and 4. The southeasterly slope of the field reflects the dip (10-14°) of the ash-flow sheet as determined from the attitude of columnar jointing in the woods above the field to the northwest. The sheet is overlain at the south end of the field by a layered lava flow which represents the basal unit of the interstratified ash-fall–lava flow sequence constituting the cliff below this lookout.

The cliff consists of a number of lava flows separated by a structureless aphanitic tuff which is softer and more porous than the lavas. Individual flow units are relatively constant in thickness whereas the inter-flow tuffs are extremely variable – ranging from a few inches to five feet in thickness. The lava flows are 5-30' thick and the flow layering dips consistently to the north from 4-28° at this location. Flow folds indicate a northerly flow direction for the uppermost three flows. Return to Highway # 3 and turn right.

28.3 Turn right along a narrow road and proceed to wood-waste dump on the north side of hill (500 yds.).

STOP 2 The flow layering at this outcrop dips uniformly 55° to the northwest. The few flow folds that have been observed here indicate a flow direction toward the northeast and parallel to the strike of the flow layering. This suggests that the lava flowed against an escarpment at this location. In the valley immediately to the north of the outcrop the flow layering forms a series of disharmonic folds varying in amplitude from a few inches to several feet. Similar folds have been observed at the base of lava flows (e.g. Stop 5) and at locations where the dip of flow layering decreases indicating a break in the original slope. A lava flow which has been in part confined to a valley 150' wide and 40' deep, and in which the flow layering is conformable to the shape of the valley, has been observed on the cliff to the east.

Return to Highway # 3 and proceed to Harvey Station.

29.3 Turn right at road 100 yds. before railway track in village; proceed a few hundred yards and leave vehicles at the public beach on the left. Proceed a quarter mile along the lake shore on the railway track to the western end of rock cut.

STOP 3 The cut consists of massive reddish-brown siltstone at the bottom overlain by two ash-flow sheets. The bottom unit is about 6-7 yards thick and the top of this unit is marked by a reddish-brown horizon. The upper ash-flow unit is 110 yards thick and extends to the top of Cherry Hill that rises above the railway cut to the south.

The bottom of the first ash-flow contains poorly sorted fragments up to 20 cm. in diameter, some of which have been completely altered to a mixture of illite and quartz. The size of the fragments decrease and become more uniform in size upward in the sheet. The base contains well preserved axiolites — the outlines of which are destroyed by post-devitrification recrystallization a few yards above. The reddish-brown horizon marks a distinct textural change from felsitic (recrystallization texture) at the top of the lower sheet to axiolitic in the bottom of the upper sheet. The changes in fragment size and textures in the basal section of the upper sheet parallel those observed in the lower unit. Poorly developed columnar joints can be observed at the top of the rock cut.

Return to the beach and proceed 300 yards northward along the road on the east side of the lake to columnar jointed outcrops.

STOP 4 The columnar jointed ash-flow shows a well-developed eutaxitic structure perpendicular to the axes of the columns and contains rock fragments and a few phenocrysts. Textures and fragment sizes at this location (the base is not exposed along the road) are equivalent to those in Cherry Hill section 30-50 yards above the base. The plunge of the column axes is 27° to the northwest and represents the steepest dip observed in the unit.

Proceed back toward beach (down dip) stopping at the outcrops at the cabin units on east side of road. These outcrops are stratigraphically higher than those immediately to the north and consist of quartz feldspar porphyry. The phenocrysts increase in abundance upward in the sheet from one percent near the base to 20%-25% as observed at this location. The quartz feldspar porphyry represents the top of the unit and is overlain by the lava flow — ash-fall sequence of the Harvey Formation (Stops 1 and 2).

Return to the vehicles and proceed to the intersection of Highway # 3 in the village. Turn right.

29.5 Turn into first road near the top of Cherry Hill and stop.

STOP 5 The outcrop along the north side of the main highway consists of lava with flow layering dipping 50° northward overlying a pyroclastic unit. Drag folds above the base at this locality indicate a northward flow direction (approximately down dip). The base of the flow contains a large number of folds without systematic shape or orientation. The dip of the flow layering can be seen to decrease northward from the main highway.

Proceed westward along Highway # 3.

33.4 Pull into parking lot of small restaurant on right.

STOP 6 The outcrops along the road and in the field behind the restaurant are of red Mississippian sandstones and conglomerates which overlie the lava flows. The transport direction for these sedimentary rocks overlying the volcanic rocks is eastward, i.e. approximately parallel to the axis of the Carboniferous basin (van de Poll, Department of Natural Resources, personal communication). Note the paucity of Mississippian volcanic clasts in the conglomerates.

Proceed westward along Highway # 3 to York Mills.

35.9 Turn right onto dirt road 50 yards before cement bridge and stop.

Proceed by foot to stream under bridge.

STOP 7 The sedimentary rocks along the bank consist of sandstones and conglomerates which dip 50-65° to the southeast. These rocks are stratigraphically below the red Mississippian conglomerates (seen at the last stop) which outcrop 300 yards downstream. The dip gradually decreases downstream from 55° to 15° over a distance of 500 yards. The high dips are anomalous and have been tentatively attributed to the affect of faulting.

The outcrop of lavas along the road parallel to and about 30' above the river level represents the westernmost extent of the Harvey Mountain Member.

TRIP B-1, by L. T. Trembath, The University of New Brunswick.

TUNGSTEN MINERALIZATION AT BURNT HILL TUNGSTEN MINE

At the Burnt Hill deposit a series of quartzites and argillites are cut by basic dikes, aplite dikes and quartz veins. The quartz veins contain a wide assemblage of minerals including wolframite, scheelite, cassiterite, molybdenite, pyrrhotite, chalcopyrite, pyrite, calcite, fluorite, topaz and beryl. As the mine is not operating, the specimen collecting is largely confined to picking over an extensive dump.

For a complete description of the mineral assemblage see Victor (1957).

LOG AND DIRECTIONS

Assembly Point — Parking Lot, Department of Geology, University of New Brunswick, Time: 10:00 a.m., Sunday, October 14.

MILEAGE

0.0	Parking lot
0.2	Leave University grounds by main gate and proceed down University Avenue
0.8	Railway Underpass. Turn left onto Queen Street
1.3	Carleton Street. Turn right
1.4	Carleton Street Bridge
1.9	Turn left on Highway 105 (Union Street)
3.7	Junction. Change to Highway 620 (Stanley)
30.7	Stanley. Change to Highway 625
32.7	Cross Creek
35.7	Green Hill. Watch carefully for sign to Maple Grove
40.1	Assemble at Maple Grove. Time 11:00 a.m. Must pay road toll of $5 per car as the last 14 miles is a private pulp and paper access road.
54.7	After 14 dusty miles park at chain marking the entrance to the mine property and proceed on foot to the mine area.

TRIP B-2, by A. J. Gordon, University of New Brunswick at St. John.

SILURIAN ROCKS OF THE FREDERICTON AREA

INTRODUCTION

Plate tectonic theory has prompted renewed interest in the nature and distribution of the pre-Carboniferous rocks of New Brunswick (McKerrow and Ziegler, 1971, 1972; Schenk, 1971, 1972). Today's excursion is devoted to illustrating some aspects of the paleogeography and tectonics of a Silurian flysch succession (Kingsclear Series, Freeze, 1936), regarded as having been deposited in a closing ocean basin.

The ready availability of recent summaries of Maritime Paleozoic geology (Potter, Bingley and Smith, 1972; Poole and Rogers, 1972; McAllister and Lamarche, 1972) makes an additional review here virtually superfluous.

A glance at the geological map of the Fredericton-Woodstock area (Map 37-1959) will show that the capital city of the province is located near the junction of two major structural and physiographic units. To the north and west (Fig. 1) fossiliferous Silu-

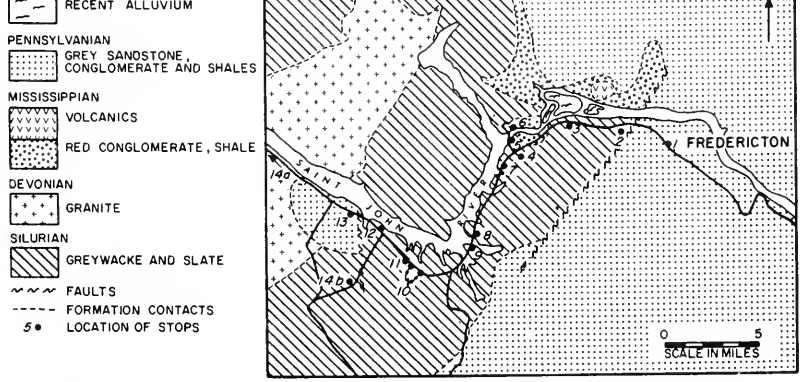


Fig. 1 Geology of the Central Saint John River Valley.

rian greywackes and slates (Gordon, 1967) have been intruded by a granitic batholith of Devonian age. While regional metamorphism of the turbidite sequence has reached only to the chlorite

Table 1 - Correlation Chart for Trip B-2

AGE		FREDERICTON	SOUTHERN NEW BRUNSWICK	SOUTHEASTEPN NOVA SCOTIA
Triassic		Not present	Lepreau Formation	Not present
Carboniferous	Pennsylvanian	Pictou Group	Boss Point Fm. Lancaster Fm.	
			Hopewell Group	
	Mississippian	Currie Mt. Volcanics Horton Equivalent	Cranberry Pt. Fm. Mt. Pleasant Volcanics	Horton Group
Devonian		Pokiok Granite	Perry Formation	Granites
Silurian		? ↑ Kingsclear Series ↓ ?	Jones Creek Long Reach ↓ ? Volcanics ?	Not present
Ordovician		Not present	↑ Charlotte Group Cookson Fm. ?	Meguma Group
Cambrian		Not present	↑ Saint John Group ↓	
Precambrian		Not present	? Coldbrook Group Greenhead Group	

grade, this has been accompanied by such intense folding and faulting that estimates of thickness have little meaning. Unconformably overlying these older rocks are Carboniferous arenaceous, non-marine sediments (van de Poll, 1966, 1967). Apart from some minor volcanic activity (Bailey, 1910) and faulting, the local Carboniferous rocks have remained essentially undisturbed since their deposition.

LOG AND STOPS

Assembly point – Front steps of the Forestry and Geology Building, University of New Brunswick, Fredericton, at 9:00 a.m. Sunday, Oct. 14th. Car park is available behind (south side) the building.

MILEAGE

0.0 Forestry and Geology Building car park. Drive south through the University's grounds to Montgomery St, then left and then right at the first road junction on to College Hill Road. Join the westbound traffic on the Trans-Canada Highway (TCH) proceed to STOP 1.

3.0 STOP 1 – Public parking area alongside the TCH. Exposure of Carboniferous (Pennsylvanian) sandstone containing plant fragments are interpreted as being part of major flood plain deposits derived from the south and west (van de Poll, 1966).

6.5 Turnoff to Springhill Quarry. Turn left and up the hill for 0.2 miles.

STOP 2 – Springhill Quarry. Sedimentology of the Silurian flysch; viewpoint over the Saint John River.

The quarry provides a source of crushed rock for construction projects in the region. The site consists chiefly of greywacke sandstones. Most are fine grained, but a limited number of feldspathic, pebbly layers form marker horizons. Between the sandstones are layers (rarely of much thickness) of black weathering, grey slate and siltstone. While joints, veins (some mineralized) and faults disrupt the rocks, there is no evidence of folding. In spite of prominent cleavages in the slates, fragmentary remains of monograptids are to be found.

Internal structures (grading, lamination, ripple-drift, etc.) in the greywackes and siltstones show that the rocks are

right way up. These structures also imply a complex, ever-changing, depositional regime, not necessarily of deep water origin. Sole markings take various forms — load casts, flame structures, groove, slide, prod and flute casts. As elsewhere in the Fredericton area, the flysch has apparently been deposited by currents moving from the east.

The parking area overlooks some basic physiographic features of the Saint John River valley. The small, isolated hill across the river is Currie Mountain, a volcanic neck or plug of Carboniferous (probably Mississippian) basalt. Beyond the hill the high ground is underlain by Mississippian arkosic sandstone, quartz-pebble conglomerates and dark shales containing **Calamites** and **Cordaites** fossils. The contact between the Silurian and Carboniferous rocks lie beneath the Saint River at this point.

7.0 Return to the TCH. Turn left towards Woodstock.

10.3 Turnoff to the Youth Training Centre.

STOP 3 — Youth Training Centre carpark. Viewpoint over the Saint John River.

In the foreground a number of low, flat islands mark the position of the Keswick River as it flows into the Saint John. The junction between the rivers has the appearance of a delta.

Return to the TCH and continue towards Woodstock.

10.8 Outcrops of Silurian flysch on the left-hand side of the road. For the next mile the road is on poorly-consolidated Carboniferous rocks.

13.3 Leave the TCH by the right hand exit towards Mactaquac and park at the viewpoint overlooking the site of the dam. Walk back to STOP 4.

STOP 4 — Rock exposure along the southeast exit to the Mactaquac Dam. Sedimentology and structure of the Silurian flysch (4a); fossil locality and additional sedimentary and structural features (4b).

4a) The sequence is similar to that of Springhill Quarry, but the succession is folded. Prominent internal structures and sole markings of the greywackes enable the numerous fold axes to be located precisely.

Folding is of concentric type. Minor folds are tight, somewhat isoclinal, upright to steeply inclined. At this locality the folds plunge gently towards the south. Two sets of cleavage are to be seen; the more prominent of the two being parallel to the axial planes of minor folds.

Fragmentary monograptids and a large Orthoceras? have been collected from dark grey, silicified slates cropping out towards the west end of the exposure. Continue around the exit road to join the TCH at STOP 4b.

4b) Pebbly greywackes are found at the northern end of this outcrop. Other noteworthy features to be seen are slates with monograptids, kink bands and tectonic lineations. These latter features prove to be small faults producing mullion-like structures marked by quartz veins in the greywackes. Walk back to the viewpoint overlooking the Mactaquac Dam.

13.8 STOP 5 — Viewpoint overlooking the Mactaquac Dam. Description of the project; discussion of the Silurian-Carboniferous relationship. Mactaquac is a rock-fill dam, impounding about 22,000 acres of water and designed to provide an ultimate generating capacity of 600,000 kw.

Across the river the Silurian rocks are exposed both below the dam and in the diversion channel leading to the generating station. Examination of these sections prior to the filling of the reservoir disclosed a structural picture quite similar to that seen at STOP 4a. In addition, two thin diabase dykes were formerly exposed below the bridge abutment over the diversion channel.

Complications of the geological structure will be examined in the section (STOP 6a) beside the generating station access road. To the right at a higher elevation along the same road, one can see the angular unconformity separating the Silurian and Carboniferous rocks (STOP 6c).

Drive across the Mactaquac Dam. Turn right along Highway 105 and then right again following the signs indicating tours of the Mactaquac site.

15.5 STOP 6 — Parking lot beside the Mactaquac generating station. Lithology and structure of the Silurian rocks (6a); Silurian fossils (6b); unconformity (6c); Carboniferous lithology and structure (6d).

6a) Deformed flute casts and other sole markings indicate a younging direction towards the northwest. While this exposure could be on the other limb of the anticline noted at STOP 4, folds occur between this point and the rocks seen in the diversion channel. Local changes in the strike and dip of the rocks can be seen towards the Carboniferous outcrop. These changes imply a different fold style than that previously seen (c.f. STOP 9).

6b) Dark grey to dark brown, rusty weathering slates contain graptolites. While the preservations are poor, it is possible to identify some fragments of monograptids suggesting a Wenlock-Ludlow age.

6c and 6d) Weakly-consolidated, calcareous, red and yellow conglomerates, arkosic sandstones, siltstones and shales overlie the Silurian rocks with angular unconformity. It is assumed that these deposits were laid down under non-marine conditions in a localized basin not much larger than the present area of outcrop. The absence of recognizable internal structures is suggestive of rapid deposition as fanglomerates involving flash floods. Later, the sediments were overlapped by younger Pennsylvanian sediments deposited under fluvial and deltaic conditions (van de Poll, 1972).

17.7 Return to the TCH, turning right following the sign marked Woodstock. (Possible additional stops).

18.6 STOP 7 – Roadside exposure with important fossil locality; sole marks on greywackes. Well preserved specimens of monograptids resembling *M. vulgaris* and *M. tumescens*. Nearby greywacke exhibits lobe-like, complexly fluted base.

22.2 STOP 8 – Exposures on both sides of the road beginning at the junction with the Mazerall Settlement Road. Sedimentology, faults, fold, dyke.

Several greywacke beds show flute casts. Tectonic lineations parallel the plunge of a fold. Strike-slip faults of limited displacement are associated with zones of 'en echelon' gashes. This faulting may also be responsible for shearing observed in a basic dyke exposed near the south end of the outcrop.

22.6 STOP 9 – Exposures on both sides of the road beginning

beyond Kelly Brook inlet. Structural features of the Silurian rocks.

Contrasts in fold styles referred to at STOP 6a are well displayed towards the northern end of the exposure, where faulting also duplicates the succession. Near the opposite end of the outcrop faulting has produced a tectonic melange.

25.4 STOP 10 — Roadside exposures at Gardens Creek. Inverted succession (10a); Silurian fossils (10b); lithology and folding of the succession, dyke (10c).

10a and 10b) The section begins as a continuously-inverted sequence extending as far as Gardens Creek. Close to the valley, carbonaceous slates contain a sparse, restricted graptolitic Wenlock-Ludlow fauna.

10c). Gardens Creek marks the core of an anticline for the rocks immediately beyond this point are right way up. Fold axes and a dyke are easily located. Way-up criteria include shallow sole markings, chiefly grooves, grading (subtle) and current laminations. The lithology is similar to that seen in Springhill Quarry, except that pebbly greywackes are absent.

26.3 STOP 11 — Roadside exposure showing folding and sole marks.

The Silurian rocks here have been folded into an asymmetrical syncline. Close to the eastern end of the outcrop there are a number of large, bulbous sole markings showing evidence of interal cross-lamination and abundant mica flakes.

28.4 STOP 12 — Right-hand roadside exposure beyond the junction with the Lake George road. This exposure is the last major outcrop of Silurian rocks along the TCH east of the Pokiok granite. The succession is vertical and youngs towards the southeast.

STOP 13 — Roadside exposure of Pennsylvanian clastic rocks.

The rocks here are lithologically similar to those underlying the City of Fredericton.

30.0 STOP 14 — If time and interest warrant, the excursion can be extended to include an exposure of the Pokiok granite (Rutledge, 1957) or a visit to the antimony mine (14b).

—TRIP B-4, by H. Greiner, The University of New Brunswick.

VERTEBRATE SITES OF NORTHERN NEW BRUNSWICK AND THE GASPE

INTRODUCTION

The collecting locales for Devonian vertebrates will be visited:

(1) The Campbellton Formation on the shore at Atholville about one-half mile west of the Interprovincial Bridge. Here, intermontane rudites, sandstones and shales contain a rich and varied flora (including *Psilophyton sensu lato*) and early fishes — osteostracians, arthrodires, and acanthodians.

(2) The world-famous Escuminac Formation (Upper Devonian), which contains additional fish groups: anaspids, antiarchs, diphoans, palaeoniscoids and crossopterygians — in the Gaspé opposite Dalhousie.

The tour will leave from the co-op Shopping Centre, Atholville, at 1.30 p.m. Sunday, October 14, 1973. Following the Escuminac visit, additional but informal visits may be made, the following morning, to important collecting sites in the Albert Formation (Upper Devonian (?)-Lower Mississippian) at Irishtown, Albert Mines and/or Norton, upon returning south.

Box lunches will be provided, but hotel arrangements, and Dalhousie Ferry fees, must be made and paid for privately.

For Road Log refer to A-7.

APPENDICES

Appendix 1 — A. L. M. McAllister

Appendix 2 — G. J. S. Govett

APPENDIX 1

by A. L. McAllister, The University of New Brunswick

ECONOMIC GEOLOGY

The complexity of geological evolution and variation in lithology within the Canadian Appalachian Geosyncline have given rise to an abundance of mineral deposits of many types, a number of which are enormous in size and of great economic value. Mining of metallic minerals containing copper, lead, zinc, silver and associated by-products, is carried out at a number of localities and non-metallic deposits of barite, fluorite, coal, salt, gypsum, celestite, asbestos, talc and a variety of building stones continue to add to the wealth of the provinces concerned.

Oil and gas have been produced in small quantities from the Carboniferous strata of southeastern New Brunswick and seeps are known from the Devonian sandstones of Gaspé. Large bodies of rock containing bismuth, tin, tungsten and molybdenum are currently under development. Gold has been produced from a number of mines in Nova Scotia, and chromite has been produced from the ultramafic masses in Quebec's Eastern Townships. Iron ore was for many years shipped from Bell Is. in Newfoundland.

A number of workers have written on the metallogenic aspects of Appalachian occurrences and the relationship between tectonic and ore-forming events (Potter, 1971; McCartney and Potter 1962; Dugas, Assad and Marleau, 1969; Beland *et al.* 1962; McAllister and Lamarche, 1972). With continued progress in delineating orogenic belts and establishing tectonic elements a better understanding of ore-forming environments will automatically follow and metallogenic concepts consequently revised and refined (Williams H., Kennedy M. J. and Neale, E. R. W. 1972).

Within New Brunswick the geosynclinal basement is exposed only in the southern part of the province where the Greenhead Group, of quartzite, argillite and limestone is overlain by a younger sequence (Coldbrook Group), consisting mainly of volcanic rocks. Exploration for metallic minerals within this basement complex has been disappointing, even though a number of small copper occurrences have been explored. Main production has been from quarries in limestone and dolomites of the Greenhead Group.

Lower Paleozoic rocks have been most productive in the Canadian Appalachian and most Pb, Zn and Cu has come from rocks of that age. In New Brunswick, the only current metallic mining operations are in the Bathurst area, where three major mines are

producing Pb, Zn, Cu and associated by-products from massive pyritic ores in an Ordovician (?) volcanic pile. A fourth major mine is now being brought into production.

Plutonism associated with the Acadian orogeny reached a climax during Devonian times and related occurrences of metallic mineralization are common. Copper skarn deposits have been explored in such places as Popelogan and Burntland Brook, small occurrences of molybdenum are associated with granite stocks at Nicholas Denys, Pabineau, Welsford, Hampstead and elsewhere, and tungsten-bearing quartz veins have been extensively explored by underground workings at Burnt Hill. Numerous vein deposits of Pb, Zn, and Cu assumed to be Devonian in age have been found, but production has come from only three, all in the area north of Bathurst.

Much of New Brunswick is covered by late- stage or post-orogenic rocks of Carboniferous age, consisting mainly of terrestrial sandstones and shales with minor tuffs, rhyolites and basalts. This sequence is broken by one group of marine limestones, shales, gypsum, salt, and potash. The limestones and gypsum support several quarrying operations and one cement plant. Extensive salt deposits are known and encouraging drill intersections of potash are being explored in the Sussex area. At least three ages of coal are known to occur and one seam has been mined at Minto for many years.

One rhyolitic vent occurs at Mt. Pleasant in Southwestern New Brunswick. Associated with it are large low-grade deposits of W, Bi, Sn, Cu, Pb, Zn, Ag, and fluorite. It is being actively developed at present.

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APPENDIX 2

by G. J. S. Govett, University of New Brunswick

EXPLORATION GEOCHEMISTRY AT THE UNIVERSITY OF NEW BRUNSWICK

INTRODUCTION

Applied geochemistry, with a strong emphasis on its exploration aspects, was introduced as a formal graduate level subject at the University of New Brunswick in 1968.

Between 1968 and the summer of 1973 twelve graduate student programmes have been completed at the University in the field of exploration geochemistry; these comprise eight in New Brunswick and one each in Spain, Guyana, Borneo, and Greece. A further three graduate programmes are in progress, two in New Brunswick and one in Greece; two or three more will commence in September, 1973.

The writer, in addition to studies in New Brunswick (Govett,

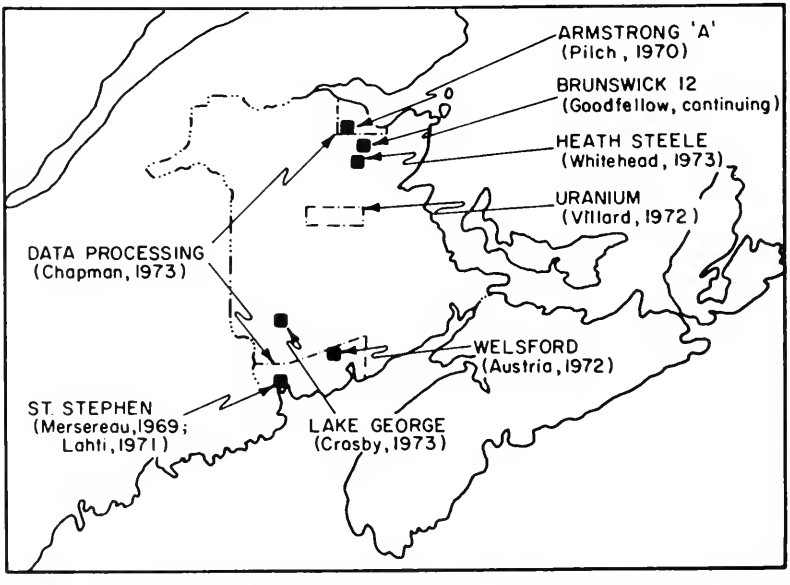

Fig. 1 Location of exploration geochemistry thesis projects in New Brunswick.

1973a), has undertaken research in Cyprus (Constantinou and Govett, 1972, 1973; Govett, 1972; Pantazis and Govett, 1973), the Philippines (Govett and Hale, 1967; Hale and Govett, 1969), and Greece (Govett, 1973b; Govett and Galanos, 1973). Work has also been done, and is continuing, on analytical methods and electrogeochemistry (Govett, 1973c; Govett and Whitehead, 1973).

The apparent diversity of effort disguises a common theme — the development of geochemical techniques to detect deeply-buried mineralization. This theme is a reflection of the firmly held belief that the world faces a shortage of a wide range of metals which can be overcome only by changes in consumption patterns and population growth rates, recycling of metals, substitutions, new processing techniques, and intensified exploration for new mineral deposits (Govett and Govett, 1972). The latter solution is the only one within the competence of the geologist; better exploration techniques and, inevitably, the development of methods to locate mineral deposits which are deeply buried beneath surficial material and those that are capped by barren bedrock, are urgently needed.

The use of geochemistry in mineral exploration depends on the measurement of chemical differences in soil, stream sediments and water, and bedrock in the vicinity of mineralization compared with the same materials in barren areas. To improve geochemical techniques, a better understanding of the processes of dispersion of elements — both primary and secondary — from an ore deposit is needed. Furthermore a clearer understanding of the origin and genetic processes of ore formation is vital.

The long-term aim of developing deep-prospecting techniques at the University of New Brunswick is being approached systematically through various stages of research:

(i) Collection of data describing the distribution of metals in earth materials for a wide range of types of mineralization, geological environment, and surface environment (all post-graduate research students).

(ii) Determination of the controls of metal distribution in earth materials under normal and mineralized conditions (Lahti, 1971; Whitehead, 1973a, 1973b; Govett, 1973c; Govett and Pantazis, 1971).

(iii) Investigation of the origin of stratiform massive sulphides (Constantinou and Govett, 1972, 1973).

(iv) Development of multivariate statistical and computer techniques which permit subtle differences in metal distribu-

tion to be detected (Govett, 1972; Pantazis and Govett, 1973).

(v) Development of more reliable and rapid analytical techniques with lower detection limits for elements of interest (Govett and Whitehead, 1973).

(vi) Electrogeochemistry to explain the primary and secondary migration of elements (Govett, 1973c).

Item (i) has necessarily predominated until recently. While it must continue to be part of all research, the other aspects now account for an increasingly significant proportion.

EXPLORATION GEOCHEMISTRY IN NEW BRUNSWICK

New Brunswick was affected, albeit lightly, by the Pleistocene Glaciation. This might be expected to cause difficulties in the use of geochemical techniques in the surface environment due to translocation of material and thick deposits of glacial debris. It has been found that glacial till deposits show little sign of movement and the glacial cover is quite thin. Geochemical response to mineralization is, therefore, good in soils and stream waters. For example, it has been demonstrated (Govett, 1973a) that the distribution of metals in soils of background areas is dictated by normal podzol soil-forming processes and that this pattern is modified near mineralization in direct response to the size and type of mineralization involved.

Soil Surveys – The typical soil profile has a variable A_{0-1} surface humus horizon, an eluviated A_2 horizon, and a brown, iron-rich B horizon which may, in places, be divided into a B_1 and a lighter coloured and less compact B_2 horizon. The C horizon is parent material, usually glacial till or fluvial-glacial deposits and, rarely, weathered bedrock. The most common clay minerals are sericite, chlorite, and illite-type minerals; expandable clay minerals are essentially absent. The pH normally increases down the profile, and both clay-sized material and organic carbon are removed from the A_2 horizon and tend to accumulate in the B horizon. The strong control of organic carbon on cation exchange capacity is evident from some characteristic physico-chemical soil data shown in Figure 2.

The typical background distribution of metals is shown in Figure 2. All metals exhibit a general trend of increasing concentration down the profile, with the exception of the impoverishment in the A_2 horizon. The base metals show characteristic differences in behaviour, with a tendency for enrichment of Pb in the A horizon, Zn in the B horizon, and Cu in the C horizon.

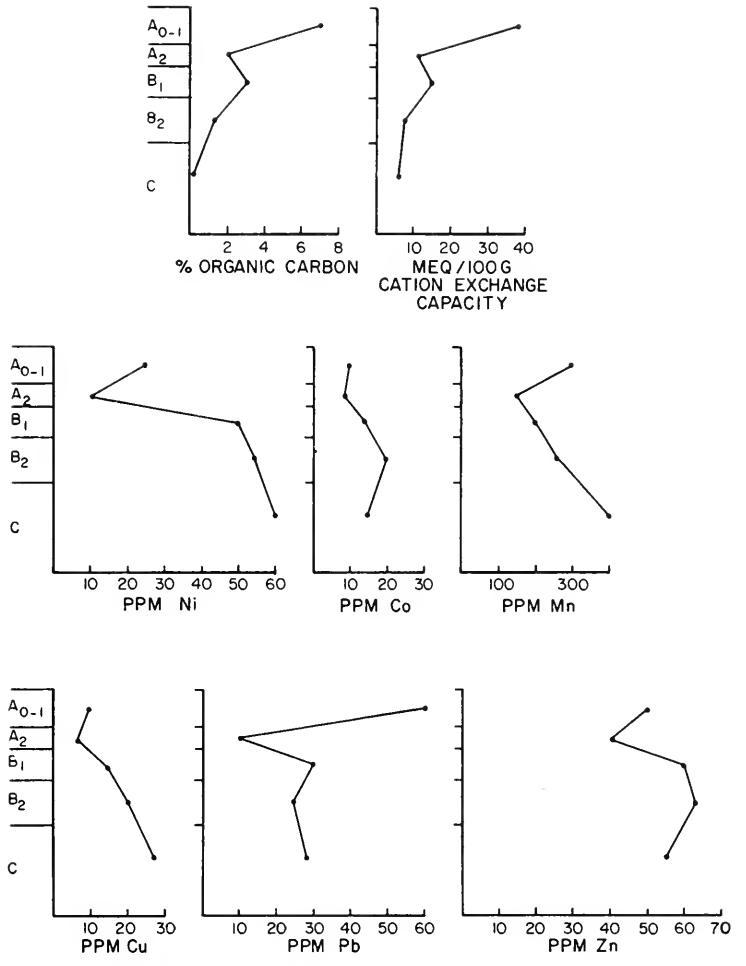

Fig. 2 Distribution of organic carbon, cation exchange capacity, and some trace elements in typical podzol soil profile, New Brunswick.

All mineralized areas tested in New Brunswick show some response in the glacial soils — even in areas where glacio-fluvial deposits and marine clays are interbedded with till (Lahti, 1971; Govett, 1973c). It is not possible to generalize on the distribution of metals in soil profiles in the vicinity of mineralization because their behaviour varies as a function of both the element

and the type of mineralization (Mersereau, 1969, Pilch, 1970, and Crosby, 1973.

The response has been classified by Govett (1973a) into four main types:

(i) Massive sulphides, rich in iron sulphides: strong positive anomalies for immobile metals and negative anomalies for mobile elements occur over mineralization; the mobile elements give broad, lateral positive anomalies either side of the ore-zone (e.g., Zn-Pb-Cu at Armstrong "A").

(ii) Vein-type mineralization with strong contrast in concentration between ore-metals in mineralization and host rocks: well-defined positive anomalies of immobile metals over ore; mobile elements show negative anomalies over ore and diffuse positive anomalies either side of the ore horizon (e.g., Sb at Lake George).

(iii) Disseminated to massive mineralization, low contrast in concentration of ore elements between mineralization and host rocks: diffuse and erratic positive anomalies which define the general area of mineralization but do not precisely define the mineralized horizon (e.g., Ni-Co-Cu at St. Stephen).

(iv) Uneconomic, narrow vein-type mineralization, poor contrast in concentration of ore elements between mineralization and host rock: sharp but very narrow and small (25 feet wide) positive anomalies over mineralization (e.g., Mo-W at Welsford).

Drainage Surveys – Drainage surveys have been widely and successfully used since the first large-scale reconnaissance geochemical stream sediment survey was undertaken in 1954 (Hawkes *et al.*, 1956; Boyle *et al.*, 1963, 1966, 1968; Fleming, 1961; Smith, 1968). Moreover, the New Brunswick Department of Natural Resources is systematically conducting a stream survey over the entire Province (Wolfe *et al.*, 1967; Wolfe and Szabo, 1968; Austria, 1970, 1971).

At the University of New Brunswick, Villard (1972) investigated the dispersion of uranium in stream sediments (Fig. 1). He showed that the concentration of uranium is strongly dependent upon the amount of organic carbon in the sediments; this was not unexpected. Of more far-reaching consequence was the discovery that all "anomalous" samples seemed to have been collected on particular days. Villard related this to stream discharge rate, which is itself a function of local rainfall. As the

stream discharge decreases during a dry period, the fine material settles out into the stream bed and sediment samples will consequently have a higher concentration of uranium (cf. Govett, 1960).

Mersereau (1969) undertook some detailed studies on the dispersion of Ni, Cu, and Co in stream water and sediments in the St. Stephen area. He found that Ni gave both the longest and the most intense dispersion train in water and in sediment. The stream sediments gave better results than the waters.

Conclusion on Stream Surveys — Stream surveys respond very well in New Brunswick where stream systems are well developed. Indeed, Crosby (1973) has shown that even regional stratigraphical-petrological variations may be recognized in the distribution of elements in stream sediments. Disruption of the drainage pattern due to glaciation — largely shown by swamps and lakes — will naturally act as precipitation barriers and tend to truncate dispersion trains; this is not a serious hazard over most of the Province. Scavenging of trace metals by Mn poses difficulties in interpretation. Seasonal variation in rainfall may possibly have a greater effect on element dispersion in sediments than has been recognized.

CONCLUSIONS

Sufficient detailed work has now been done to show that soil geochemistry is effective in New Brunswick, and the main empirical controls on the type and intensity of dispersion have been recognized. Similarly, the techniques of rock geochemistry developed elsewhere (Govett, 1972) are proving to be applicable in New Brunswick (Whitehead, 1973a). Greater long-term significance is attached to the studies directed towards providing more fundamental explanations for metal dispersion near mineralization; it is believed that major improvements in techniques suitable for deep prospecting can only be developed if the processes of element dispersion are more clearly understood. Field and laboratory studies are in progress, and some promising results are being obtained Govett (1973c).

Stream sediment surveys have been proved to be effective in the Province as reconnaissance and detailed follow-up techniques for nearly twenty years. The role of stream sediment surveys is not likely to change significantly, but their effectiveness in New Brunswick and elsewhere can probably be increased through a more thorough documentation of the climatic and physio-chemical controls on element dispersion and, especially, by better in-

terpretative techniques. However, inherent variabilities in the samples place severe limitations on sophisticated statistical data treatment (Pantazis and Govett, 1973). Stream sediment surveys are probably the only geochemical technique which will not benefit significantly from improvements in analytical techniques; analytical errors probably are already insignificant when compared with sampling errors.

The genesis of ore deposits, and especially the origins of zoning of metals in ore deposits is being investigated both in field geochemical studies and in specific laboratory experiments. Exploration geochemistry at the University of New Brunswick continues to be practical and applied in its aims; it attempts to achieve these aims through theoretical and academic studies.

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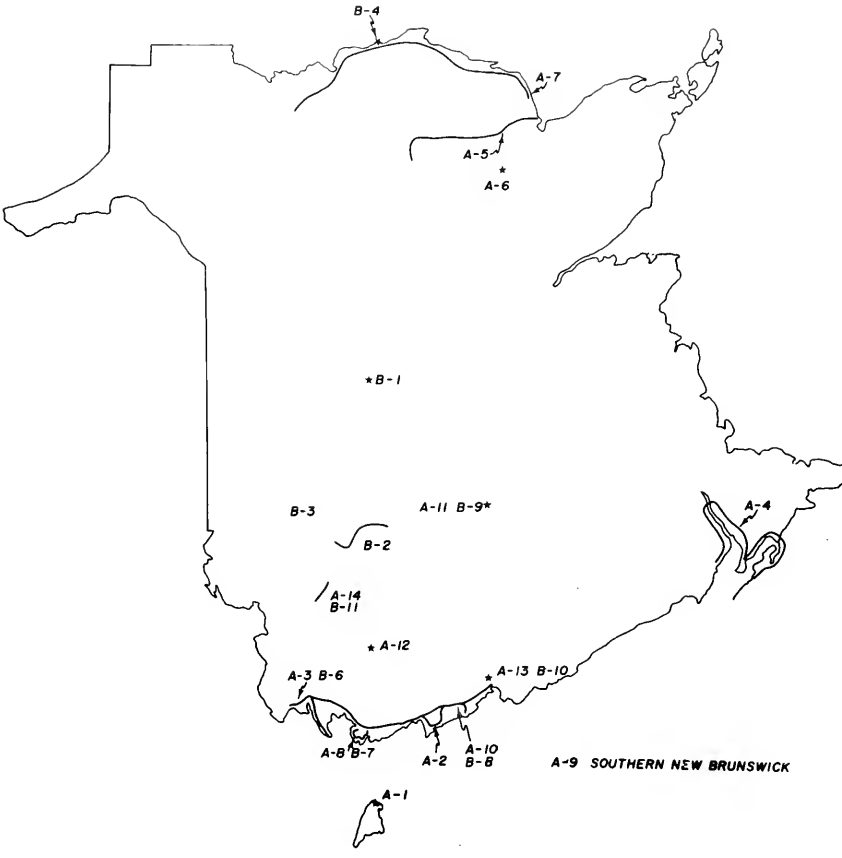
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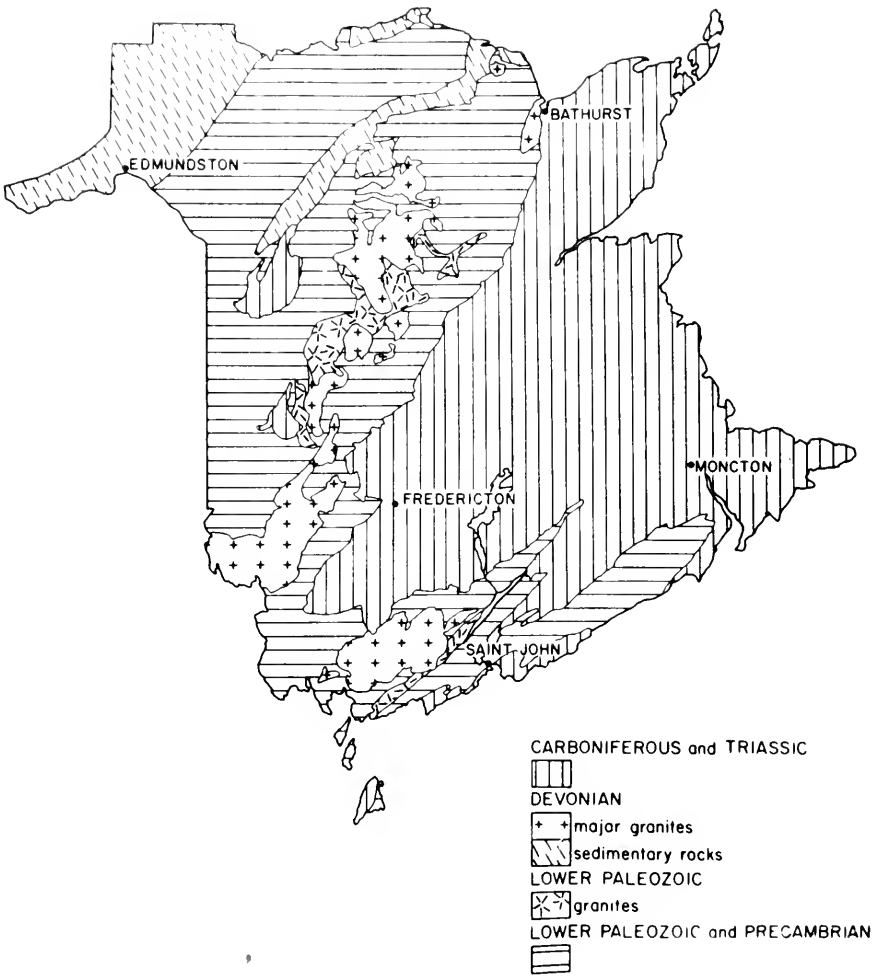
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